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July 2003

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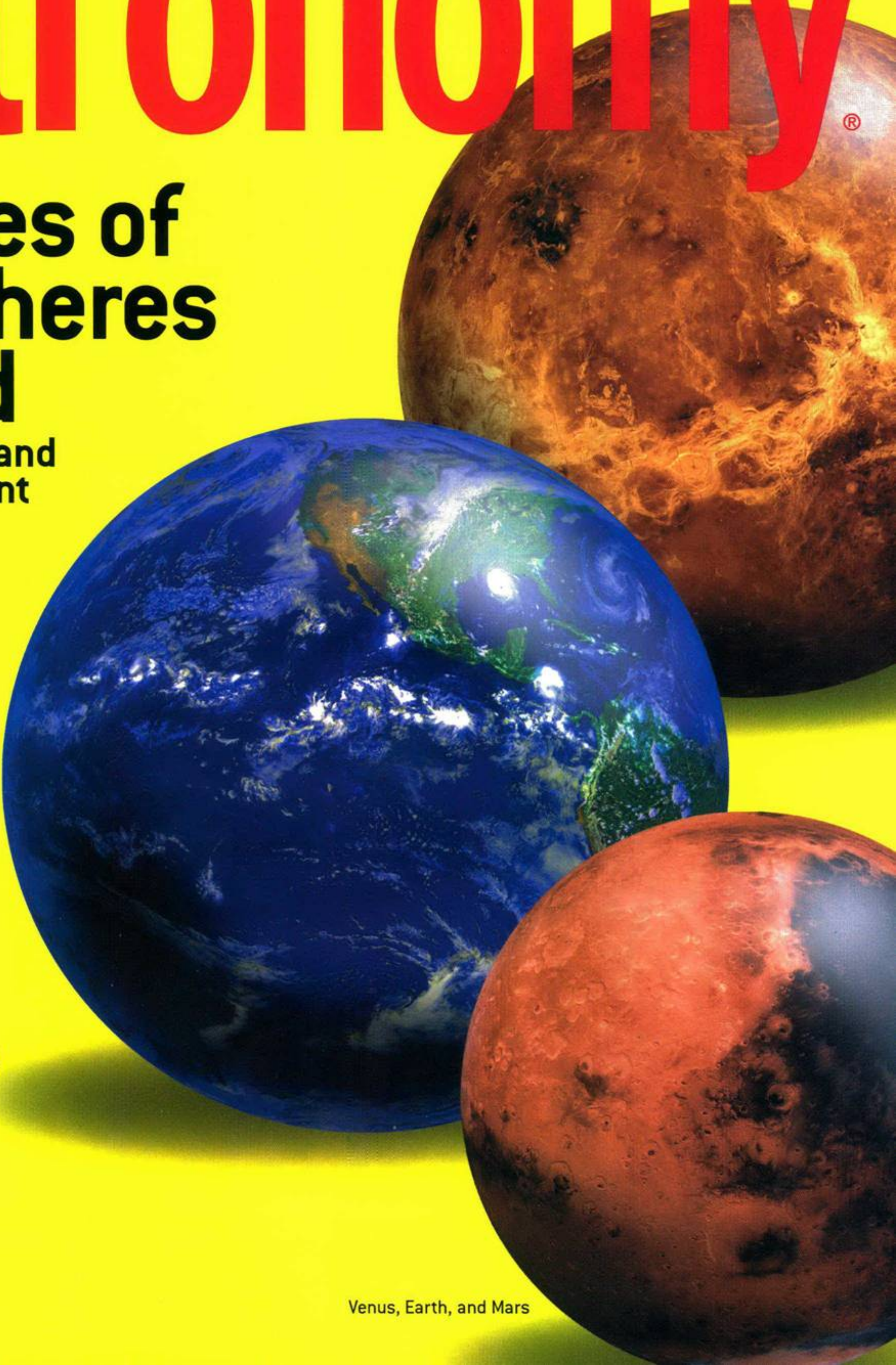


Venus, Earth, and Mars

LXD55

Choose from six Meade Schmidt-Newtonians, each with Autostar® or Electronic Controller — from $579, *complete!*

Observe ***hundreds*** of galaxies, nebulae, and star clusters of all types ***your very first night out,*** and hundreds more the next night out, simply by pressing the Autostar GO TO pushbutton. Watch as the telescope fast-slews at 4.5°/second, locating each object — from the brightest to the most obscure — and placing it automatically, unerringly, and precisely in the telescopic field. Or choose one of the new EC-models with 4-speed, dual-axis Electronic Controller, telescopes upgradable at any time in the future to full GO TO status just by adding the Autostar hand controller.

Complete with #497 Autostar Controller:

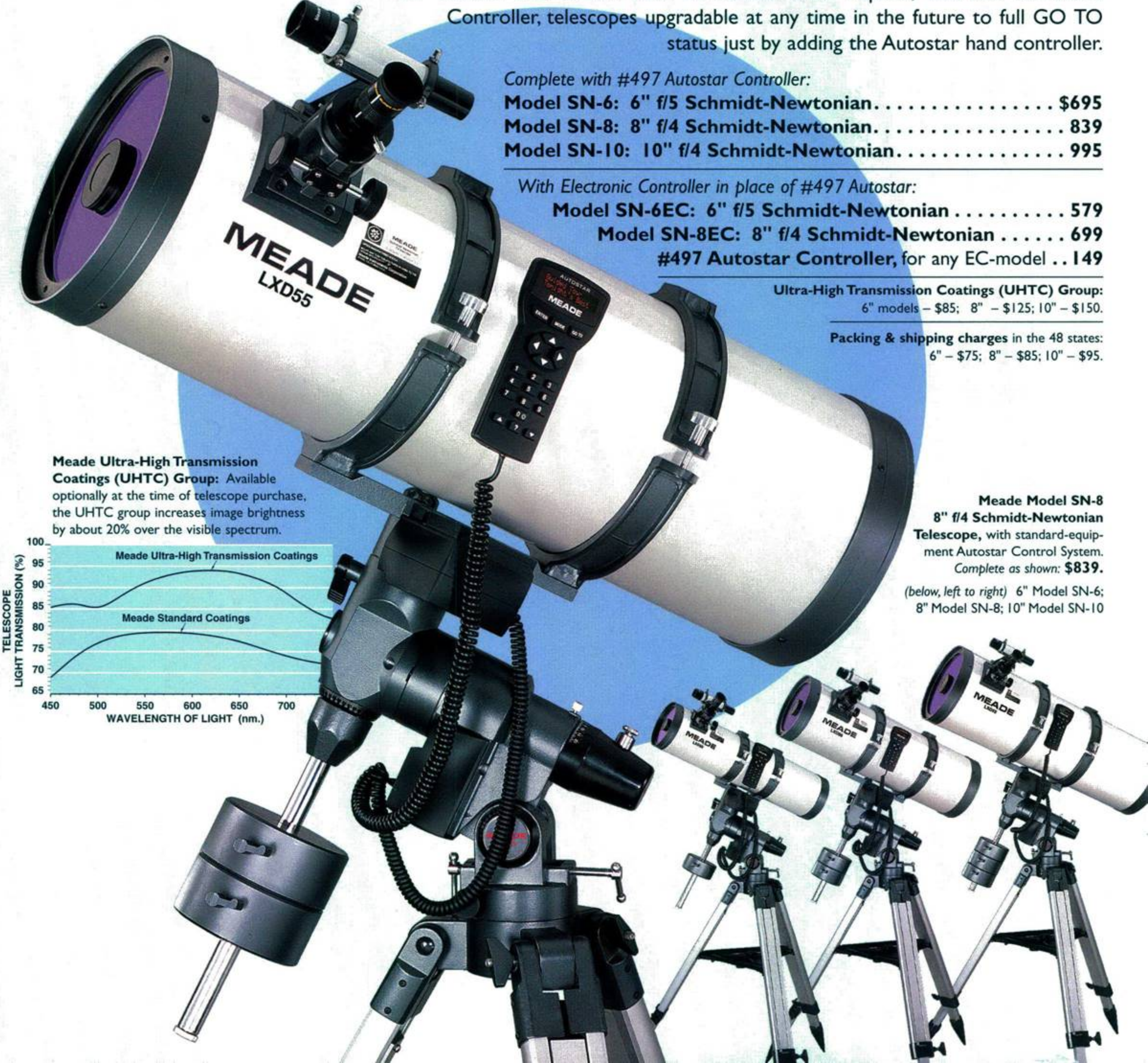
Model SN-6: 6" f/5 Schmidt-Newtonian	**$695**
Model SN-8: 8" f/4 Schmidt-Newtonian	**839**
Model SN-10: 10" f/4 Schmidt-Newtonian	**995**

With Electronic Controller in place of #497 Autostar:

Model SN-6EC: 6" f/5 Schmidt-Newtonian	**579**
Model SN-8EC: 8" f/4 Schmidt-Newtonian	**699**
#497 Autostar Controller, for any EC-model	**149**

Ultra-High Transmission Coatings (UHTC) Group: 6" models – $85; 8" – $125; 10" – $150.

Packing & shipping charges in the 48 states: 6" – $75; 8" – $85; 10" – $95.



Meade Model SN-8 8" f/4 Schmidt-Newtonian Telescope, with standard-equipment Autostar Control System. *Complete as shown:* **$839.**

(below, left to right) 6" Model SN-6; 8" Model SN-8; 10" Model SN-10

Meade Ultra-High Transmission Coatings (UHTC) Group: Available optionally at the time of telescope purchase, the UHTC group increases image brightness by about 20% over the visible spectrum.
Meade Ultra-High Transmission Coatings
Meade Standard Coatings
TELESCOPE LIGHT TRANSMISSION (%)
100
95
90
85
80
75
70
65
450
500
550
600
650
700
WAVELENGTH OF LIGHT (nm.)

Images with the Meade Model SN-8 8" f/4 Schmidt-Newtonian telescope. To obtain the images at right H. Tokumitsu attached a Fuji FinePix S2Pro digital camera to the eyepiece-holder of his unmodified, factory-standard Meade Model SN-8. Tracking was accomplished on the LXD55 equatorial mount with the telescope's R.A. drive at the sidereal rate; no guiding was performed during the period of the exposures. *(top to bottom)* **The Great Nebula in Orion (M42)**; a composite of two 3-minute exposures. **The Pleiades (M45)**; a composite of two 2-minute exposures. **The Andromeda Galaxy (M31)**; a composite of four 3-minute exposures.

Many amateurs have used Meade LXD55-Series Schmidt-Newtonians to obtain stunning images of the Moon, planets, and deep-space with commonly-available consumer digital cameras. Meade "fast" flat-field optics, combined with smooth worm-gear tracking systems and the Autostar controller, permit even the beginning amateur to obtain images like those at right.

"Here in Japan, where Meade is the number one Schmidt-Cassegrain brand by a large quantity, your new LXD55 Schmidt-Newtonians have received a lot of attention. My personal choice was the 8" f/4 model, and I have been extremely pleased with the telescope in every respect. The equatorial mounting is solid and vibration-free for both high-magnification visual observing and for astrophotography. The optics are excellent, with sharp, round stellar diffraction images across the large field of view, and without the coma visible in fast parabolic Newtonians. Not only does the telescope give incredible views of deep-space objects and star fields, but it is a fine lunar and planetary instrument as well. Jupiter shows numerous cloud belts with a great deal of structure within the belts; Saturn's ring divisions and disk markings are very nicely resolved.

"My latest application of the 8" LXD55 Schmidt-Newtonian is to image deep-space objects with the Fuji FinePix S2Pro digital camera. Although this camera was developed as a consumer product, not as an astro-imaging device, the results I have obtained are most rewarding. I am enclosing a CD-ROM of some of my images. All images were obtained simply by attaching the camera body to the telescope, exposing ***unguided*** *for 2 to 3 minutes, and then compositing several images. In my 20 years as an amateur astronomer I have never obtained such impressive results with so little effort!* **— H. Tokumitsu, Tokyo, Japan.**

SUPER PLÖSSL 40mm

Buy a **$650** Super Plössl eyepiece set for your LXD55 telescope for only **$99!** *See ad on page 9 for details!*

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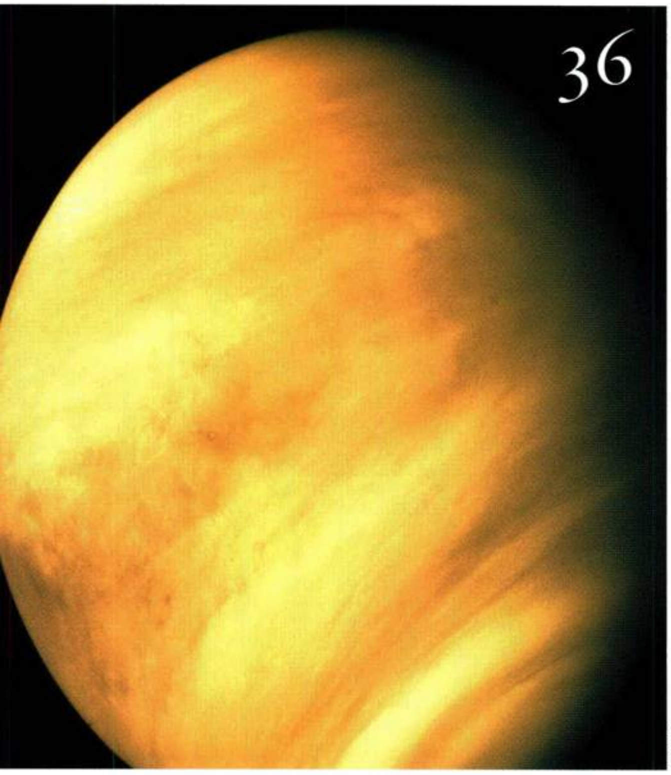

JPL/NASA

features

COVER STORY

36 Goldilocks and the three planets

What was it about Earth's atmosphere that made our planet "just right" for life, while Mars and Venus became inhospitable? Although the phrase "greenhouse gases" has taken on threatening overtones in recent years, these gases historically were responsible for creating an Earth (and perhaps even a Mars) capable of sustaining life. NAOMI LUBICK

SPACE EXPLORATION

42 Trial by fire

The breakup of the shuttle Columbia is only the latest in a string of spaceflight mishaps that range from the tragic to the absurd. Bob Berman argues that risk is inevitable in the quest to go where no one has gone before. BOB BERMAN

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Astronomers are learning how to combine light from more than one telescope to create virtual telescopes with incredible resolution. ROLF DANNER AND RAY JAYAWARDHANA

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71 Sagittarius

Gorgeous, bright nebulae, star clusters, dark nebulae, and star clouds lie within the heart of the Milky Way in Sagittarius. TOM POLAKIS

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78 Simple skyshooting

Learn to record the ever-changing sky with a regular camera and sturdy tripod. Examples abound in this how-to piece on astrophotography. JOHN SHIBLEY

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Are you looking for a special vacation retreat — one with dark skies, large telescopes, and friendly guides? Star Hill Inn is the place for you. TOM POLAKIS

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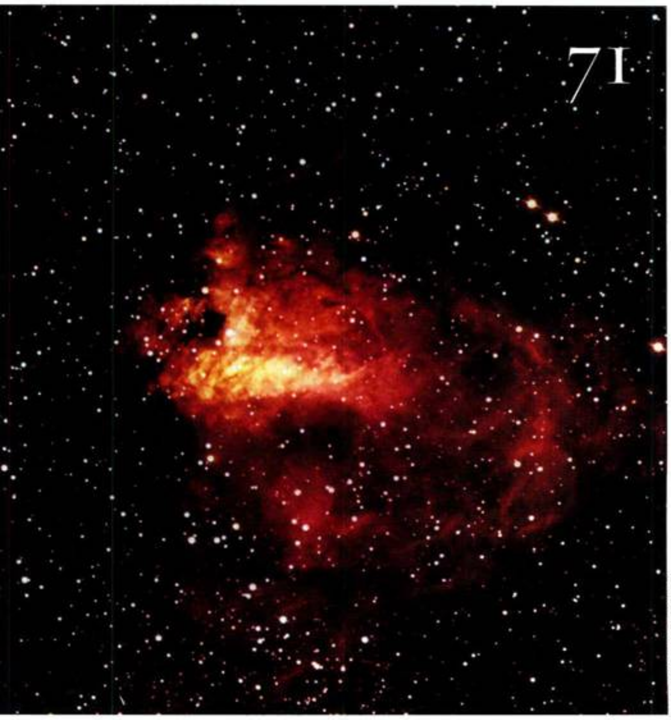
86 Gunning for the gas giants

Uranus and Neptune are surprisingly easy to spot with binoculars and telescopes. Use this handy guide to locate them over the next several months. ALISTER LING



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RICHARD JACOBS

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Astronomy
Mysteries of atmospheres revealed

ON THE COVER
The blue planet Earth, with its massive oceans and thriving life, stands in stark contrast to the scorched surface of Venus (top) and the cold, rusty deserts of Mars (bottom). The chief reason: Earth's intermediate atmosphere has the right density and composition to trap a modest amount of heat, allowing liquid water to remain on the surface for long periods. NASA/JPL

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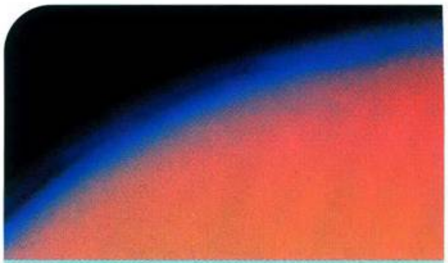

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{ THIS MONTH IN *ASTRONOMY* }

BY DAVID J. EICHER

A tale of three planets

Despite the war in Iraq, the continuing threat of terrorism, and the general disharmony among nations in the world today, we're fortunate to be living on Earth in the year 2003. Our blue planet has the right blend of temperatures and gases to make existence and all the troubles of our daily lives possible, whereas the other rocky planets in our neighborhood — Mars and Venus — have met other fates.

In "Goldilocks and the three planets" (page 36), California science writer Naomi Lubick attacks the question of how the terrestrial, martian, and venusian atmospheres got to where they are today. Planetary scientists are reconsidering the amount and importance of methane in the atmosphere of early Earth, a debate that reopened in the 1990s with Carl Sagan and his former student Christopher Chyba leading the way. One idea is that early life may have consisted of microbes that thrived on carbon dioxide, synthesizing it and hydrogen into vast amounts of methane and water.

Some 2.2 to 2.5 billion years ago, however, Earth's atmosphere made a sudden jump to an oxygen-rich climate. This change may have swiftly killed off many of these methanogens, paving the way for later, more sophisticated critters.

Different puzzles must be solved for us to understand the evolution of atmospheres on Mars and Venus. The Red Planet somehow went from a long-ago warm and wet to a present-day cold and dry. Venus turned itself inside-out in the most masochistic drama of any planet we know. These processes left Mars too cold for life — at least in the long run — and Venus way too hot. Check out Lubick's story for other details of our fortune.

Astronomy columnist Bob Berman has contributed a story, "Trial by Fire" (page 42), on the Columbia disaster and what it means for the future of space exploration. Berman also considers other space-related tragedies, such as the Challenger explosion, the Apollo 1 fire, and Soviet explosions at Baikonur. In addition, he surveys a number of other mishaps along the difficult, ambitious road humanity has taken to reach out from our blue planet. Is space exploration so technologically sophisticated that we are destined to suffer periodic catastrophes? Berman's essay intrigues and informs us about the hazards of space travel — a story to keep in mind when America's space program reawakens.

If you want something offbeat, look into Tom Polakis's story on the Star Hill Inn (page 82). This facility, located near Las Vegas, New Mexico, pioneered the concept of an astronomical resort. It offers inky black skies and a variety of telescopes ranging from a 7-inch refractor to a 22-inch Dobsonian. Visiting the facility, which amounts to a vacation at an upscale lodge, has produced many memorable nights of observing for North American amateur astronomers over the last dozen years.

Yours truly,

DAVID J. EICHER
Editor

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ETX-90AT Astro Telescope	**$595**
ETX-105AT Astro Telescope	**795**
ETX-125AT Astro Telescope	**995**

Ultra-High Transmission Coatings (UHTC) group increases image brightness by about 20%: ETX-90AT– $50; ETX-105AT– $75; ETX-125AT– $95

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ETX-70AT Astro Telescope	**299**

Packing & shipping (ETX, Autostar, & Tripod): ETX-90AT — $30; ETX-105AT — $35; ETX-125AT — $40; ETX-70AT — $20.

Meade ETX-125AT
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(top to bottom)
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8" Model SC-8.

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8" – $85; 5" – $85; 6" – $95.

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LXD55 EMC
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SUPER PLÖSSL 9.7mm
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PLÖSSL 20mm
SUPER PLÖSSL 26mm
SUPER PLÖSSL 32mm
SUPER PLÖSSL 40mm

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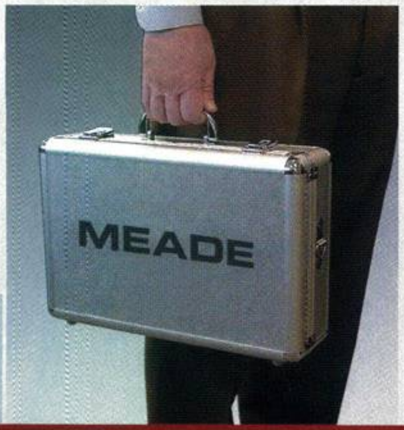

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Identical to the Microfocuser supplied with Meade LX200GPS telescopes, but provided with a separate handbox for use with all other Meade SCT models (e.g. LX10, LX50, LX90, LX200) or for Schmidt-Cassegrains of other brands. Threads directly to the telescope's rear cell. Permits extremely precise focusing of the image during visual or photographic applications; during CCD applications maintains precise image centration on even the smallest CCD chips. Operates at four speeds, from extremely slow to fast; accepts both 2" and 1.25" eyepiece barrels. Requires 8 x AAA (user-supplied) batteries. **$249.95** (9.85)

CCD-Photo-Visual Flip-Mirror Systems

Use with any brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XTE, ST-7, or AP1, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XTE, or ST-4 through ST-10; or AP2, AP7; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue — each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25". **$149.95** (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$129.95** (5.26)

MA12mm Illuminated Reticle Astrometric Eyepiece

A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **$119.95** (4.26)

Series 4000™ 8mm – 24mm Zoom Eyepiece

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25". **$219.95** (6.38)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm. **$79.95** (5.26)

ETX® Hard Carrying Cases

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, optional eyepieces, erecting prism, table tripod, hand controller, etc. Includes steel latches & key.

#774 Case for ETX-90 models: **99.95** (8.58)
#776 Case for ETX-105EC: **99.95** (8.58)
#775 for ETX-125EC: **149.95** (13.38)

#64 T-Adapter for ETX®

Threads to photo port of all ETX-90, ETX-105, and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **$34.95** (3.86)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of longer focal-length Barlows. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

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#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes UHTC-coated (95%+ reflectivity) precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders. **#929** or **#930,** each: **$119.95** (6.85)

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Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces). **$42.95** (3.86)

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Meade-engineered for smooth, rapid focusing with ETX-90, -105, or -125. Four-speed operation from coarse to microfine. Standard-equipment hand controller accepts one 9v. (user-supplied) battery and focuses all ETX telescopes. Or focus through the telescope's Electronic Controller (EC) or through Autostar.

#1244 Electric Focuser for all ETX-90 and ETX-105 models: **$119.95** (6.85)

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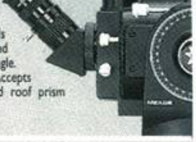
#932 45° Erecting Prism for ETX®



For terrestrial observing with any ETX-90, ETX-105, or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics. **$49.95** (3.86)

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Threads into the front lens-cell and effectively inhibits the formation of dew on the lens surface.

#670 for ETX-60/70	**19.95**
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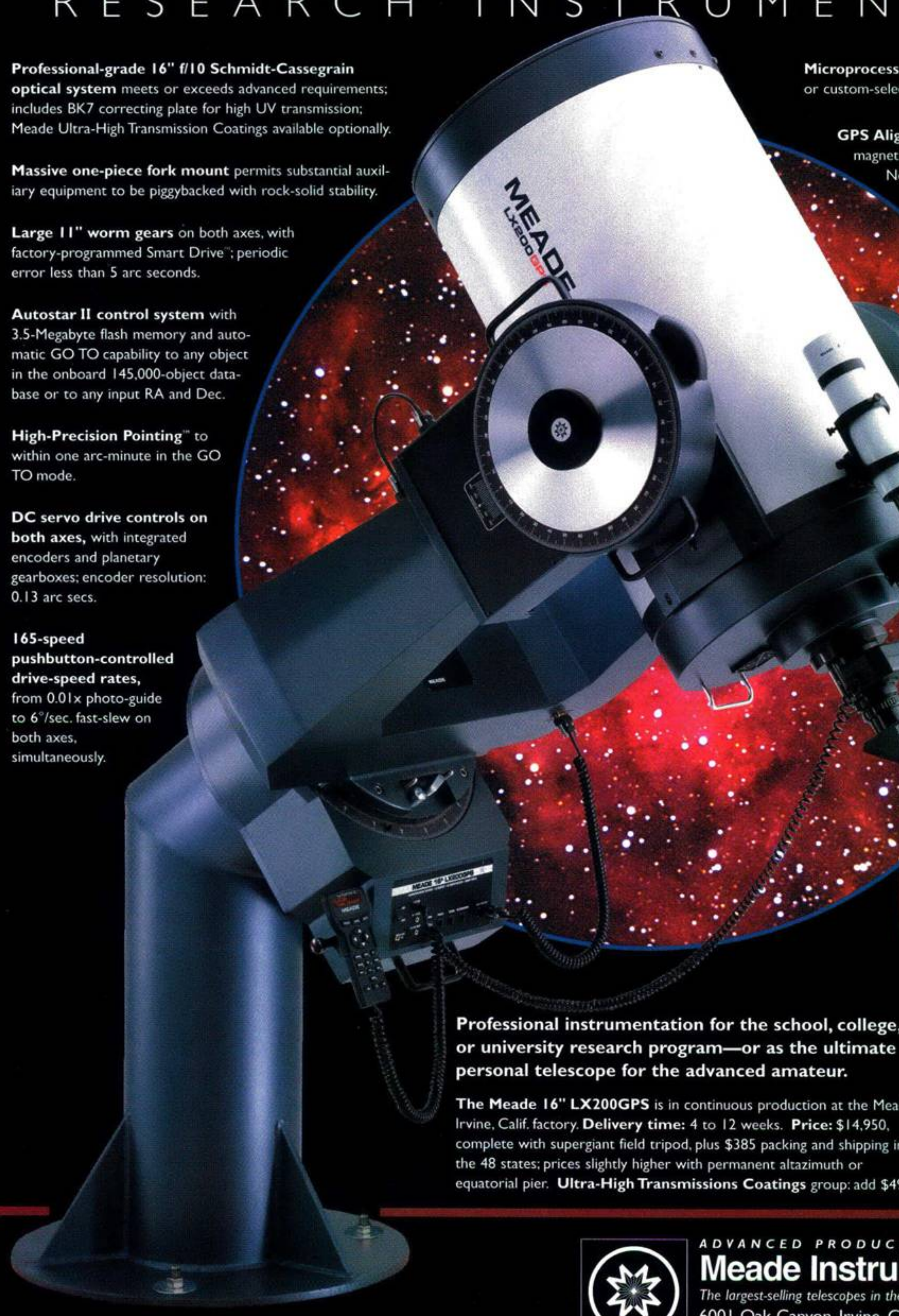
MEADE LX200GPS

RESEARCH INSTRUMENTATION



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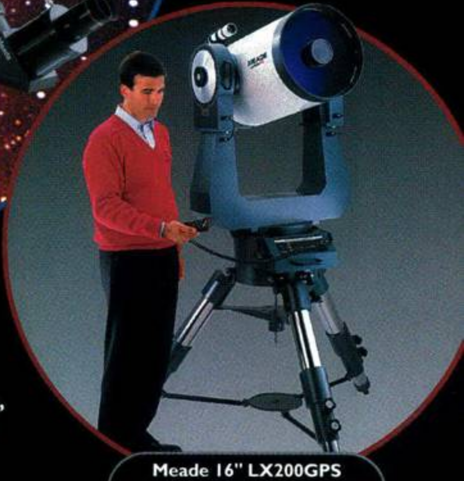

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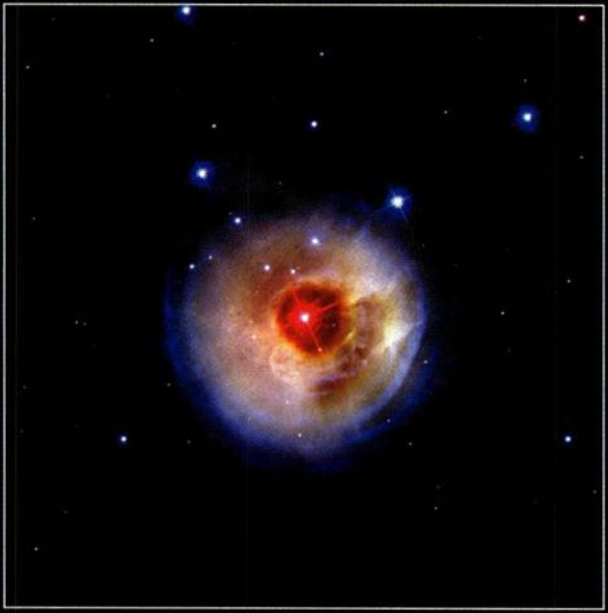
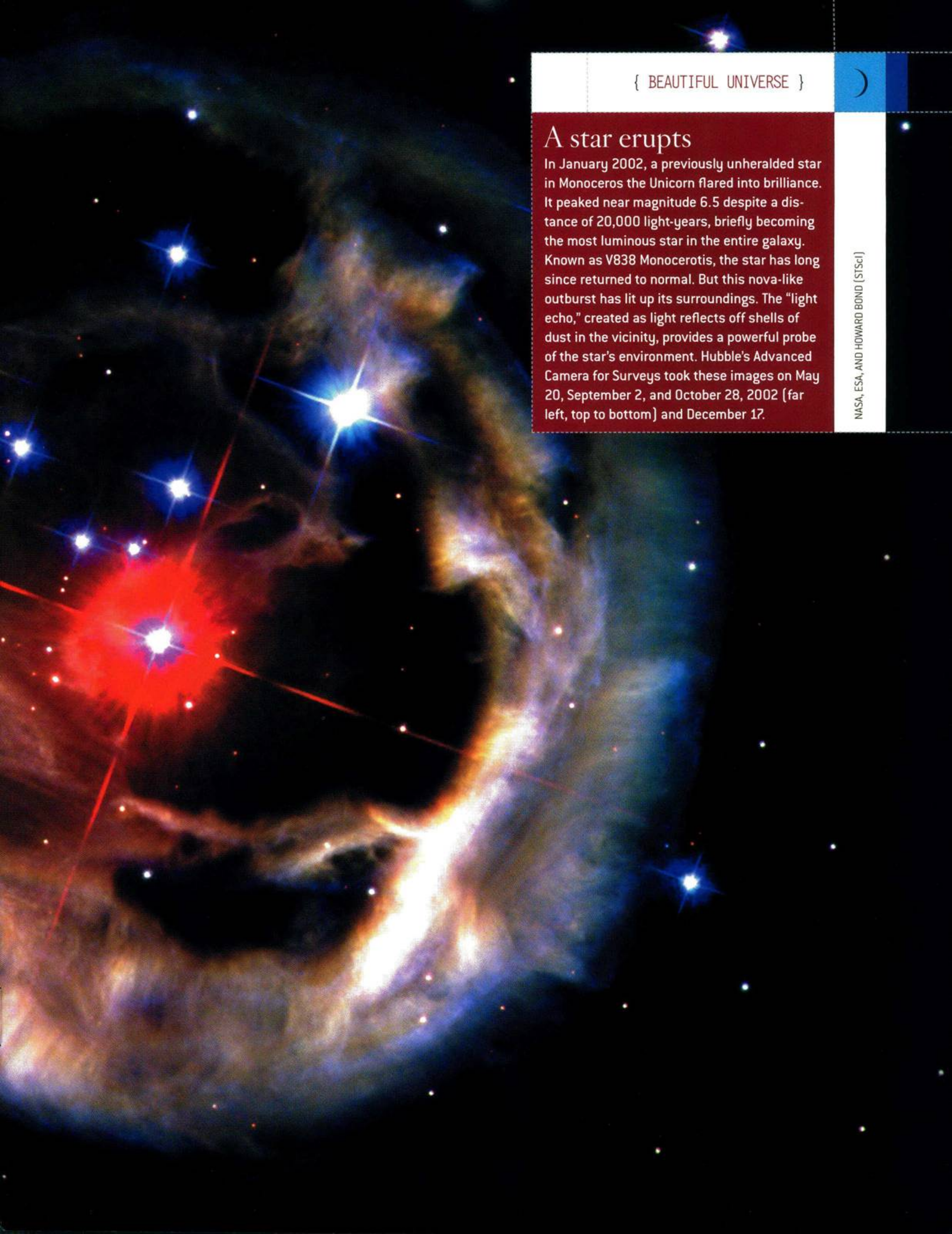


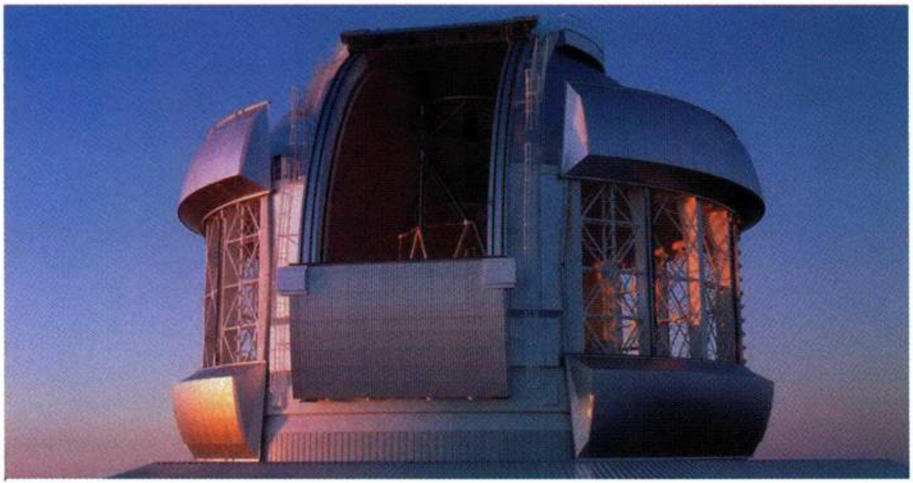


A star erupts

In January 2002, a previously unheralded star in Monoceros the Unicorn flared into brilliance. It peaked near magnitude 6.5 despite a distance of 20,000 light-years, briefly becoming the most luminous star in the entire galaxy. Known as V838 Monocerotis, the star has long since returned to normal. But this nova-like outburst has lit up its surroundings. The "light echo," created as light reflects off shells of dust in the vicinity, provides a powerful probe of the star's environment. Hubble's Advanced Camera for Surveys took these images on May 20, September 2, and October 28, 2002 (far left, top to bottom) and December 17.

NASA, ESA, AND HOWARD BOND (STScI)

Mauna Kea matters



MAUNA KEA is home to some of the world's most powerful telescopes, including the 8.1-meter Gemini North instrument. NEELON CRAWFORD [POLAR FINE ARTS]/GEMINI OBSERVATORY/U.S. NATIONAL SCIENCE FOUNDATION

In "Big eye on the universe" (April), Bob Berman mentions the conflict Mauna Kea is facing between native Hawaiians and astronomers. But I believe this issue is not really a conflict at all. Both sides must realize that they have the same goal but are on different paths, and there's no reason why the two similar paths must clash.

Astronomers try to learn about our home, including how it was built and how it will hold up. In that search we learn about ourselves. Indigenous Hawaiian natives do the same thing. Through faith, they seek knowledge about their place in the universe and their future. Through tradition they look at their past, much like astronomers look at quasars.

Finally, their attempt to protect their preeminent tool to do all of this is no different from an astronomer's attempt to protect the night sky. Our development does to their cause what a bright parking lot does to astronomy.

As a professional astronomer, I may be in the minority when I say this, but I believe Mauna Kea presents a unique tool to both groups. A compromise consisting of a permanent freeze on large-scale construction and repainting the domes seems a likely solution. Respectful dialogue between members of both groups would also help ease the tension.

If both sides understood that they share the biggest quest in history — to understand the universe — then a compromise would work. It's time to think of the common goal and realize how much more effective, and fun, it would be to go there together. — **AARON PRICE,** CLINTON B. FORD ASTRONOMICAL DATA & RESEARCH CENTER, CAMBRIDGE, MASSACHUSETTS

I would like to clarify an inaccurate quotation that was attributed to me in "Big eye on the universe." On page 42, Bob Berman quotes me as saying that the Keck telescopes lose time due to "astronomer inefficiency." Nothing could be further from the truth. In fact, it's only the highly efficient use by our award-winning astronomers that has enabled such breakthrough discoveries as the acceleration of the universe, the existence of planets around nearby sunlike stars, and evidence of a black hole in the center of our galaxy.

The point I wanted to make was that, as great as the Keck telescopes have been, there is still room to improve the system efficiency. Advances in technology, science, and computing power have enabled giant leaps in ground-based astronomy. For example, new instruments are gathering spectra of 130 galaxies in a single exposure, while new detectors are able to measure subtle changes across a single pixel. Within the next ten years these and other improvements could help us produce significantly more science each night from the telescopes.
— **LAURA K. KRAFT,** W. M. KECK OBSERVATORY

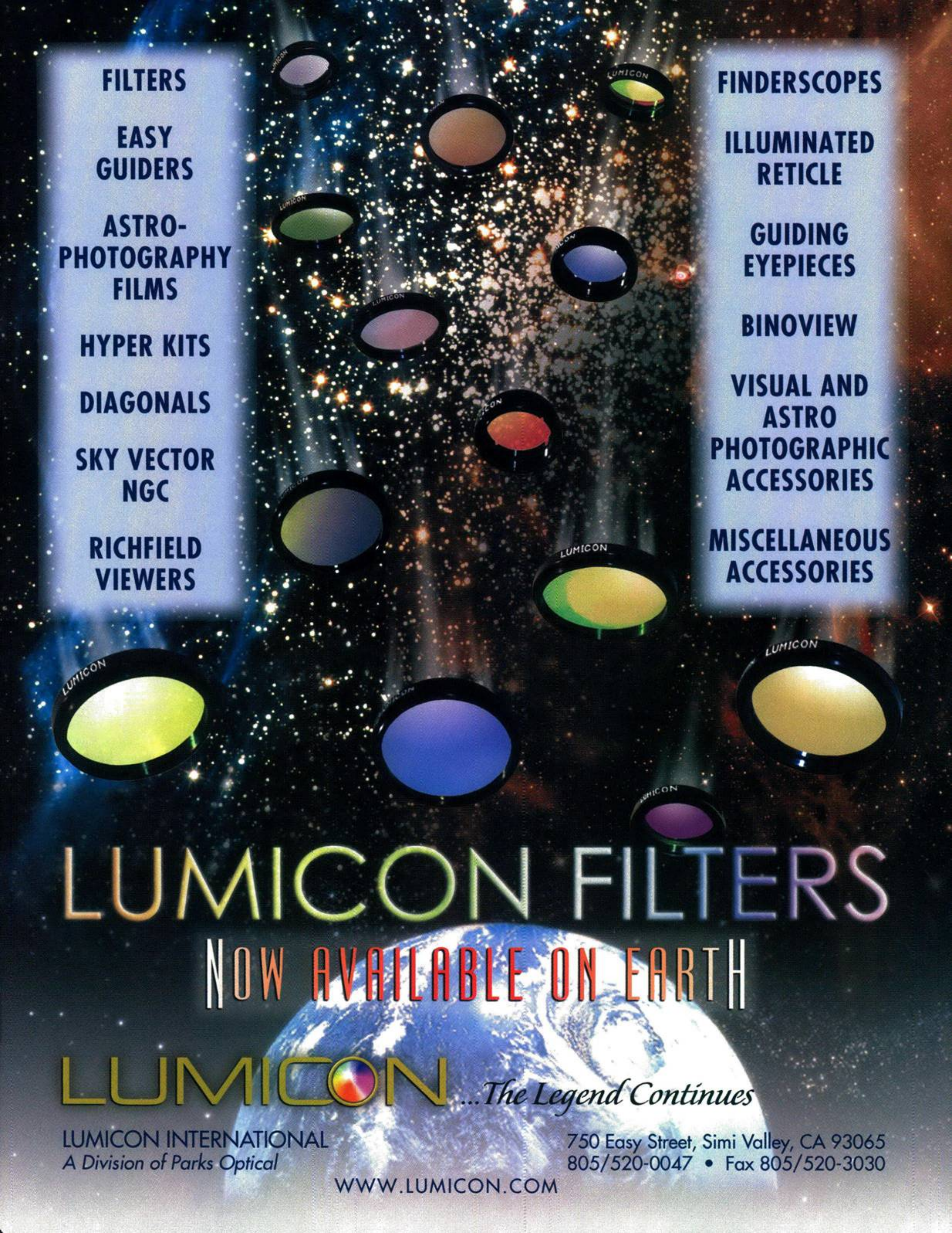
Human achievement

I enjoyed "Will dark energy steal all the stars?" in the March issue. But I took exception to the quote by physicist Tom Banks in which he calls human beings "a minor phenomenon." Intelligence is the crowning achievement of the universe. Could there be anything more amazing? If we were insignificant, we never would have become smart enough to realize our small yet important place in the universe.
— **ROGER SARGENT,** ALBION, PENNSYLVANIA

Correction

On page 38 of the April issue, the caption should read "4,200 meters" rather than "4,200 feet." — ***ASTRONOMY* EDITOR**

We welcome your comments. Send letters to Astronomy Letters, P.O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.



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BY BOB BERMAN

Colors of a summer night

Did you know...?

Early summer often delivers the year's faintest Full Moon — as well as the most orange. Two reasons. Humidity maxes out in July and this reddens celestial bodies. Also, thick air near the skyline dims every low object with the dinosaur-like term *extinction*. And July's Full Moon on the 13th is in-the-dirt low.

It virtually matches June's (on the 14th) as co-winners of the prize for "year's lowest sky object." Even at their 1 A.M. loftiest, both lurk five Moon-widths beneath where the winter Sun sits on the solstice. This is, like, bass-singer low.

These are the lowest Full Moons in 12 years. The explanation is the Moon's orbit, which wobbles like a dropped dinner plate. Its 18.6-year tilt-cycle currently makes the Moon slide below the ecliptic just where the ecliptic itself is lowest, in the dark alleyways around Sagittarius.

When the Moon is only 10° above the horizon (equal to a clenched fist at arms' length), its light struggles through six times more air than December Full Moons. When on the horizon, its light comes through 13 times more air. Dust, crud, and humidity are amplified 13 times over. And summer air typically has 10 to 15 times more water vapor than winter's. Put all these effects together and you'll see a Honey Moon. Its amber beauty is lost on moon-aware but colorblind dogs and those insane coyotes that rattle my family's dishes with their lunatic howls.

A low Moon always looks bigger, too — the famous Moon illusion. It's actually a psycho-optical effect caused by placement next to distant earthly objects like chimneys, instead of being dwarfed within the sky's vastness.

People, alas, habitually look straight ahead, not up. So the July Full Moon hovers in the visual field, unlike the winter version, which is mostly high overhead. Finally, since summer nights are often spent outdoors at sporting events, carnivals, and such, it all adds up to a Moon with extraordinary presence.

Back in March's article about "green," moonlight's colors were mentioned. I subsequently asked a group of students to make observations during March's Full Moon and the results were, um, illuminating. Yes, away from lights, green-blue dominates any moonlit scene. The main reason, as had been noted, is the Purkinje shift that makes blue-green the peak region of retinal sensitivity in low light.

That explains moonlight's enduring reputation for painting scenes turquoise. Of course, moonlight is merely reflected sunlight and thus contains all colors; a simple spectroscope confirms that reds and yellows are abundantly present. But the eye has a hard time perceiving warm hues in dim light. (In very dim light, all colors become a shade of gray.)

Here's a fine-point, something I hadn't realized before: Since an object's brightness depends on how far it is from your eyes (intensity falls off with the square of distance), a moonlit apple, tangerine, or lemon held in your hand may look faintly red, orange, or yellow. But that same fruit placed 60 feet away will be gray because it then becomes too dim to excite the eye's cone-shaped color cells. In bright moonlight, human retinas hover on the border between using rods and cones. This autumn, when distant hills of aspens or maples blaze with gold or crimson by day, they'll look grayish in moonlight because there's no green to show up.

We're left with an intriguing paradox. June and July's Full Moons are often orange or amber — but their light turns our world aquamarine!

Color controversy also surrounds July's second brightest nighttime object — Mars. This month, the Red Planet's explosive growth crosses two thresholds. At mid-month it breaks the magnitude –2 barrier, making it far-and-away the brightest "star." It also surpasses 20″ in size, enough disk-width to display impressive detail when the seeing is steady. Its color?

To lay people, Red Planet is a description, not just a title. Beep! Wrong. For more than a quarter century, editors have ignored available true-color images and almost exclusively published NASA's enhanced-color versions. I don't blame the media: The falsely reddened images are not only more vivid, they're also how people expect Mars to look.

But this month everyone can see Mars's true color. After 1 A.M. on non-humid nights, a quick glance at the southern sky shows Mars high enough to display its naked-and-unashamed actual tint: yellow, if dust storms are swirling there; yellow-orange, if the martian weather's clear. Never red, ever. Match it up with a paint store chart and see for yourself.

The summer sky offers another pale color, a subtle pastel blue. It's mixed with white, yet blue nonetheless: Spica. With a color index of –0.23, Virgo's alpha sun is July's bluest bright star.

Its muted azure and the explosively brightening Mars, both above the Moon's cool greens, supply rebuttal to those who think the natural night is colorless.

Then, after drinking in summer's naked-eye panorama like a fine "light" wine, uncork the dust cap to release the telescope's own color-geyser — Albireo, Uranus, Mu Cephei, and the rest.

And give thanks you're not a beagle.

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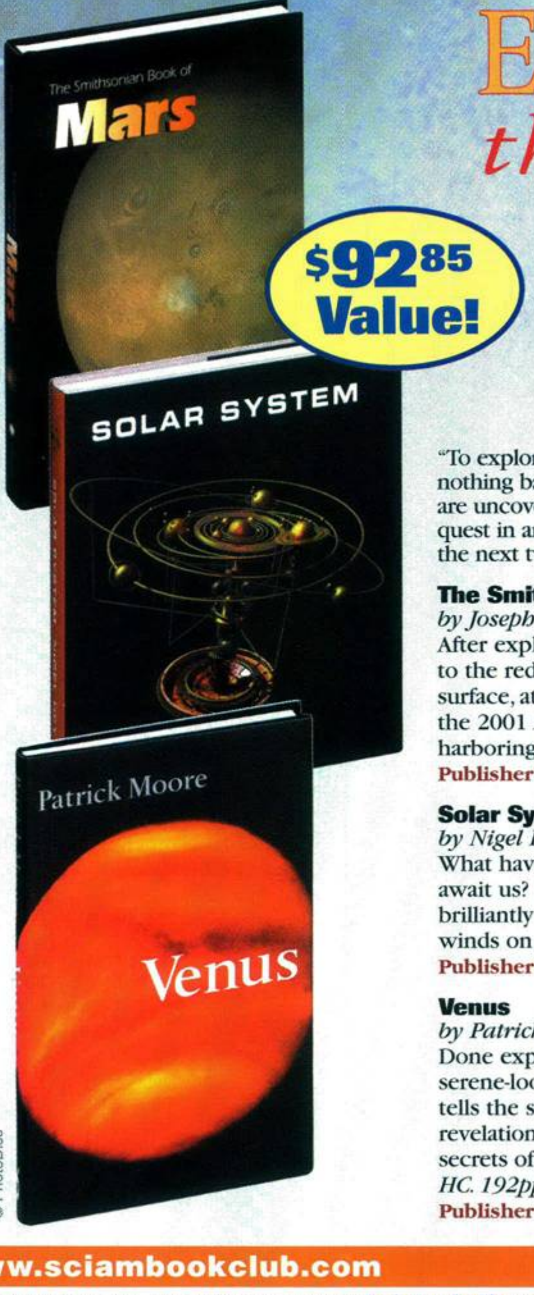

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What have we learned about the solar system so far and what wonders await us? Chock-full of color photographs from space missions, this book brilliantly exposes the wonders of the solar system—from 6,000 mph winds on Jupiter to the diamond rains of Neptune. *HC. 272pp. 2002.*
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Done exploring Mars? Then journey to Earth's other neighbor. Under its serene-looking cloud cover, Venus hosts a hellish environment. Moore tells the story of this "jewel of the sky," from ancient observations to the revelations of the *Venera, Vega*, and *Magellan* probes penetrating the cloudy secrets of a planet whose external beauty belies its inhospitable surface. *HC. 192pp. 2002.*
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BY GLENN CHAPLE

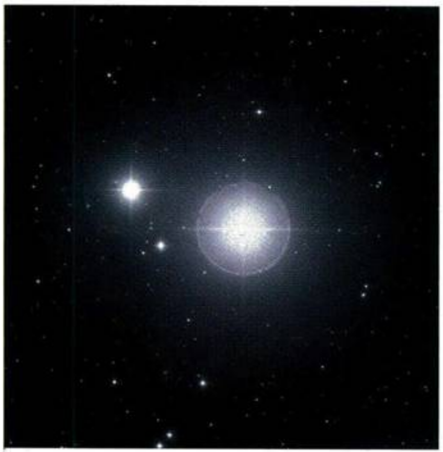
Double vision

This month, we're going to see double. And we won't have to overindulge at happy hour to do it — we're going to look at a double star: two stars that appear close together in the sky. In some instances, the proximity is an illusion and the stars are light-years apart — they just happen to lie along the same line of sight. We call these faux duos "optical double stars." Most doubles, however, are gravitationally bound systems that orbit a common center of gravity — these are known as binary stars.

Gravitational bonding isn't limited to pairs — there are triple and even multiple stars. Castor in Gemini (currently disappearing to our west) is actually a sextuple (six) star system. Astronomers estimate that as many as half of all stars, including 10 of the 25 nearest our solar system, are double or multiple systems. Alpha Centauri, the closest star to the Sun, is a triple.

Why get excited about double stars when we can train our telescopes on cosmic masterpieces like the Andromeda Galaxy or the Hercules Cluster? To me, it's their simple beauty. There's something magical about a twin binary (or "double double") like Gamma Arietis, whose stars shine from the inky darkness of space like a cat's eyes. When a double combines two stars of different temperatures, the color contrast can be downright stunning. Albireo in Cygnus pairs a golden yellow star with a fainter blue star. The sight of the two rarely fails to elicit a gasp of surprise and wonder from first-time viewers.

Besides their visual appeal, there's another reason why I'm particularly fond of double stars. They were the topic of the very first astronomy article I ever wrote — back in 1977. The article appeared in a publication called *Deep Sky Monthly* (later, *Deep Sky* magazine), whose editor was a high-school student named Dave Eicher. (I wonder whatever became of him?)



CAN YOU NAME THE STAR that sits between the glimmering pair of Alcor (left) and Mizar (right)? Its enthusiastic discoverer thought he had stumbled on a new planet.

DIGITIZED SKY SURVEY/PALOMAR MOUNTAIN OBSERVATORY/STScI

One of the best-observed double stars is Mizar — the middle star in the handle of the Big Dipper. It was the first double discovered with a telescope (in 1650), the first photographed (1857), and the first of its kind I ever observed (1963). The sight was so inspirational that I went on to observe more than 1,500 double, triple, and multiple stars with the 3-inch reflecting telescope that was my mainstay in those days.

Look carefully at Mizar with the unaided eye and, if your vision is reasonably good, you should see a faint star close by. This is Alcor, and it lies about 1/5 of a degree (12 arcminutes) away. There is some question as to whether or not the two form a binary system. Although both belong to the cluster that includes the five inner stars of the Big Dipper, the two may actually be as much as three light-years apart — too distant to form a viable binary pair.

Mizar and Alcor are truly an eye-pleasing sight in binoculars, but we must view the pair with a telescope to get a real surprise. Mizar is again doubled! Its stars are a mere 14.4 arcseconds apart. (One arcsecond is 1/60 of an arcminute or 1/3,600 of a degree — the apparent width of a penny viewed from a distance of two and a half miles.) Nevertheless, Mizar A and Mizar B are easily seen through a telescope that magnifies 30 to 60 times. The pair of cosmic diamonds share similar temperatures and color (both are white), but they aren't identical twins — Mizar A is about four times brighter than its companion.

There's another interesting chapter to their story. Some double stars are too close to be separated visually with a telescope. But a periodic shift in a star's spectral lines can betray its binary nature. In 1889, Mizar A was the first such spectroscopic binary discovered. About 20 years later, Mizar B was also found to be a binary. Mizar is a quadruple star!

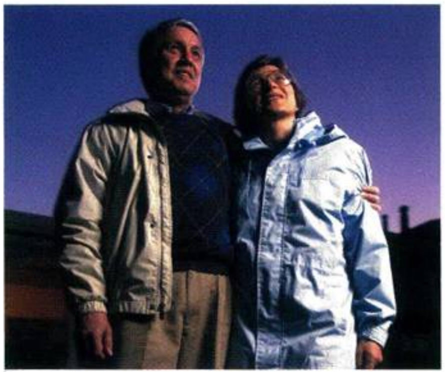
Here's a question for you trivia buffs. The photograph on this page shows how Mizar and Alcor appear through the historic 200-inch Hale Telescope at Palomar Mountain Observatory. A third, fainter star appears in the same field. In 1723, an astronomer mistook this star for a newly spotted planet. He gave it an interesting name in honor of his king. What is the name of this star? We'll have the answer next month.

So go outside and try to see double. I think you'll agree that these binary stars will double your pleasure and double your fun. Clear skies! ■

BY WILLIAM SCHOMAKER

Andrei Linde

As a 24-year-old graduate student, Andrei Linde's genius for theoretical physics and cosmology blossomed behind the Iron Curtain at the Lebedev Physical Institute in Moscow in 1972. Only a decade later, when the world was still subsumed by a cold war between the superpowers, Linde was swiftly gaining renown for his nearly single-handed resurrection of inflationary cosmology — putting Alan Guth's then-crippled Big-Bang-fix back on firm footing. Remaining in Russia until the fall of the Soviet Union in 1989, Linde now calls Stanford University's department of physics home. There, along with fellow physicist and wife Renata Kallosh, his current projects straddle the interface between physics, the universe, and human consciousness and will no doubt continue to usher revolution in cosmology.



ANDREI LINDE and his wife Renata Kallosh.

LINDA A. CICERO/STANFORD NEWS SERVICE

It's been said that one night you woke your wife stating, "I know how the universe began." What circumstance fueled this sudden epiphany?

I still distinctly remember the night in 1981 when I woke up Renata to tell her about my vision of a huge universe emerging from the interior of a single microscopically small bubble.

In 1980, Alan Guth proposed a solution for problems that plagued the standard Big Bang theory. But Guth's inflation (or exponentially rapid expansion) scenario had problems, too. He assumed that after inflation, as the supercooled, unstable vacuum-like state that fueled the expansion decayed, huge bubbles would have formed and collided to heat the universe.

The problem, which he realized immediately, was that the bubble walls made the universe extremely inhomogeneous and unrealistic. After a year of work, Guth and Erick Weinberg conceded in an 80-page paper that inflation could not be fixed.

Fortunately, the mail system from the United States to Russia was notoriously slow at the time, so I didn't receive Guth and Weinberg's paper until 1982, after I had already solved inflation's inhomogeneity problems. I found that under certain conditions inflation could continue inside each of the bubbles. Each bubble grows so large that we do not see the inhomogeneities produced by the bubble wall collisions.

How do technical and/or social constraints affect our understanding of the universe?

Like it or not, we are approaching the limits of technology in some arenas. Physical processes in the early universe involved energies billions of times higher than the energies produced at today's most powerful particle accelerators. As a result, it becomes increasingly more difficult to test new physical theories. With respect to cosmological observations, however, there remains ample room for technological improvements that can sharpen our reach and understanding of the universe.

Does the universe exist if we're not looking?

Common sense tempts me to say, "Of course, the universe exists, even if we're not looking." Yet the issue of reality in quantum cosmology is hardly straightforward. So the best I can say is that everything we see occurs in such a way as if the universe is real and exists even if we are not looking. These words *as if* are very important, and I am not ready to remove them from my answer.

Is our universe alone?

Whether our universe is alone or one of many, it may appear to act like one of many in either case. According to inflationary theory, our universe may consist of multiple, exponentially large parts. For all practical purposes, each such part looks like a separate universe with different laws of physics operating in it.

Which presently requires greater suspension of disbelief — extra dimensions and multiple universes or the existence of God?

Nobody will take the existence of extra dimensions and multiple universes seriously if one finds a simpler cosmological theory and an easier way to construct a consistent theory of elementary particles. Disbelief appears only when one makes unnecessary assumptions and stops the search for a better explanation of the mysteries of the universe.

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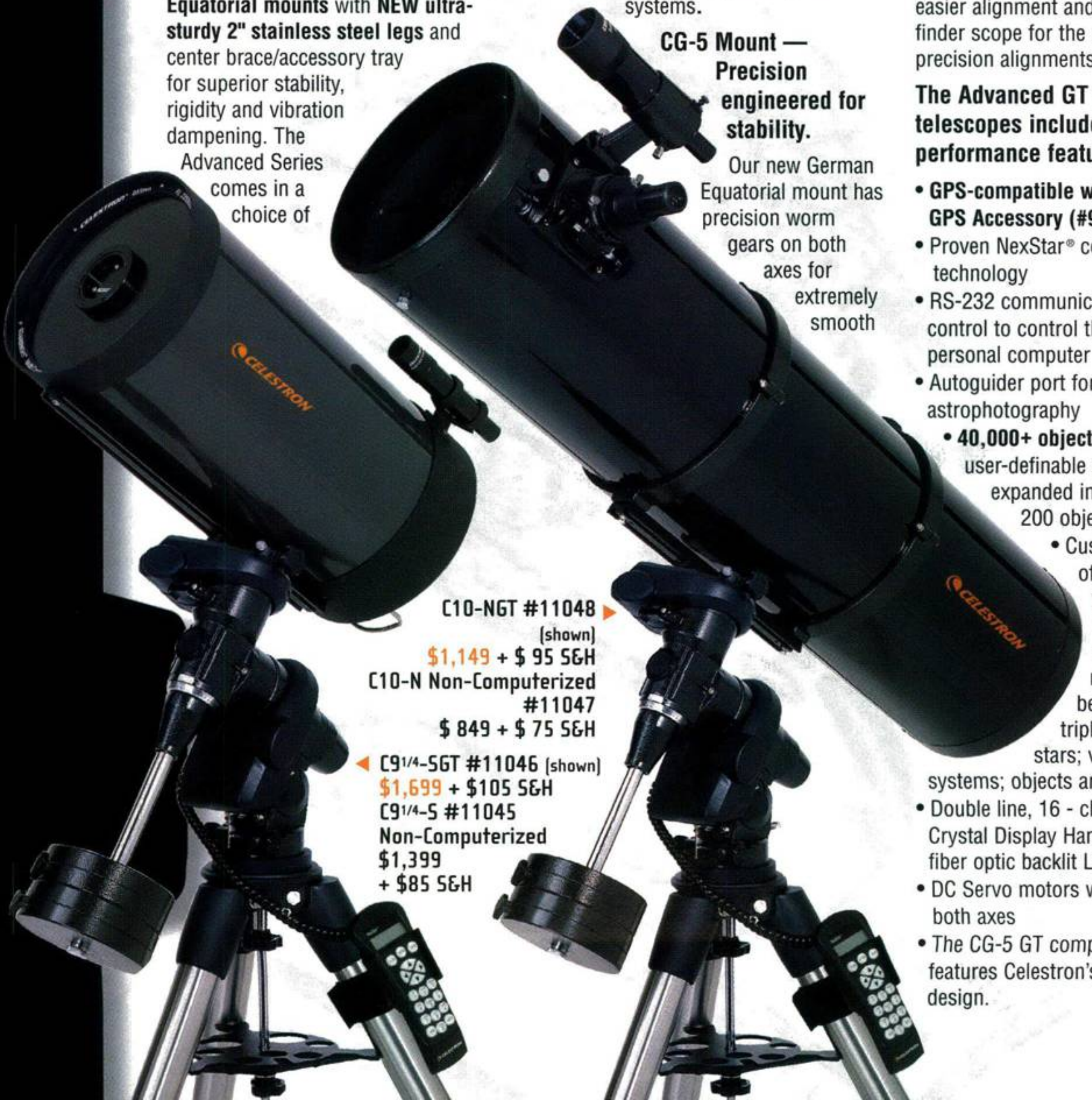

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Optical Design	102mm (4.0") refractor	127mm(5") Schmidt-Cassegrain	150mm (6.0") reflector	150mm (6.0") refractor	203mm (8") Schmidt-Cassegrain	200mm (8.0") reflector	235mm (9.25") Schmidt-Cassegrain	254mm (10") reflector
Focal Length	1000mm f/10	1250mm f/10	750mm f/5	1200mm f/8	2032mm f/10	1000mm f/5	2350mm f/10	1200mm f/4.7
Finderscope	6x30	6x30	6x30	9x50	6x30	9x50	6x30	9x50
Mount	CG-4 Equatorial	CG-5 Equatorial	CG-4 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial
Eyepiece	1-1/4" – 20mm (50x)	1-1/4" – 25mm (50x)	1-1/4" – 20mm (38x)	1-1/4" – 20mm (60x)	1-1/4" – 25mm (81x)	1-1/4" – 20mm (50x)	1-1/4" – 25mm (94x)	1-1/4" – 20mm (60x)
Star Diagonal	1-1/4"	1-1/4"	n/a	1-1/4"	1-1/4"	n/a	1-1/4"	n/a
Accessory tray	yes	yes	yes	yes	yes	yes	yes	yes
Tripod	Aluminum	2" Stainless Steel	Aluminum	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel
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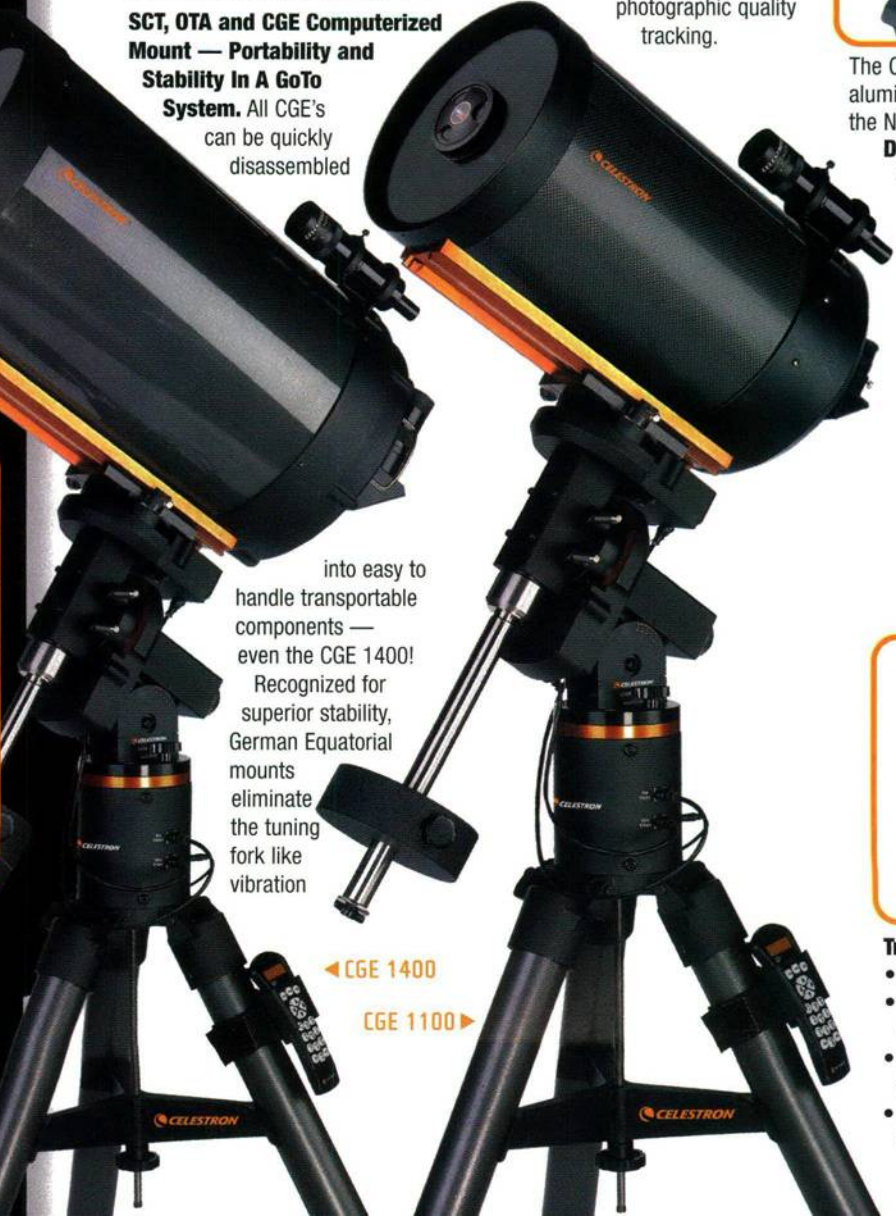

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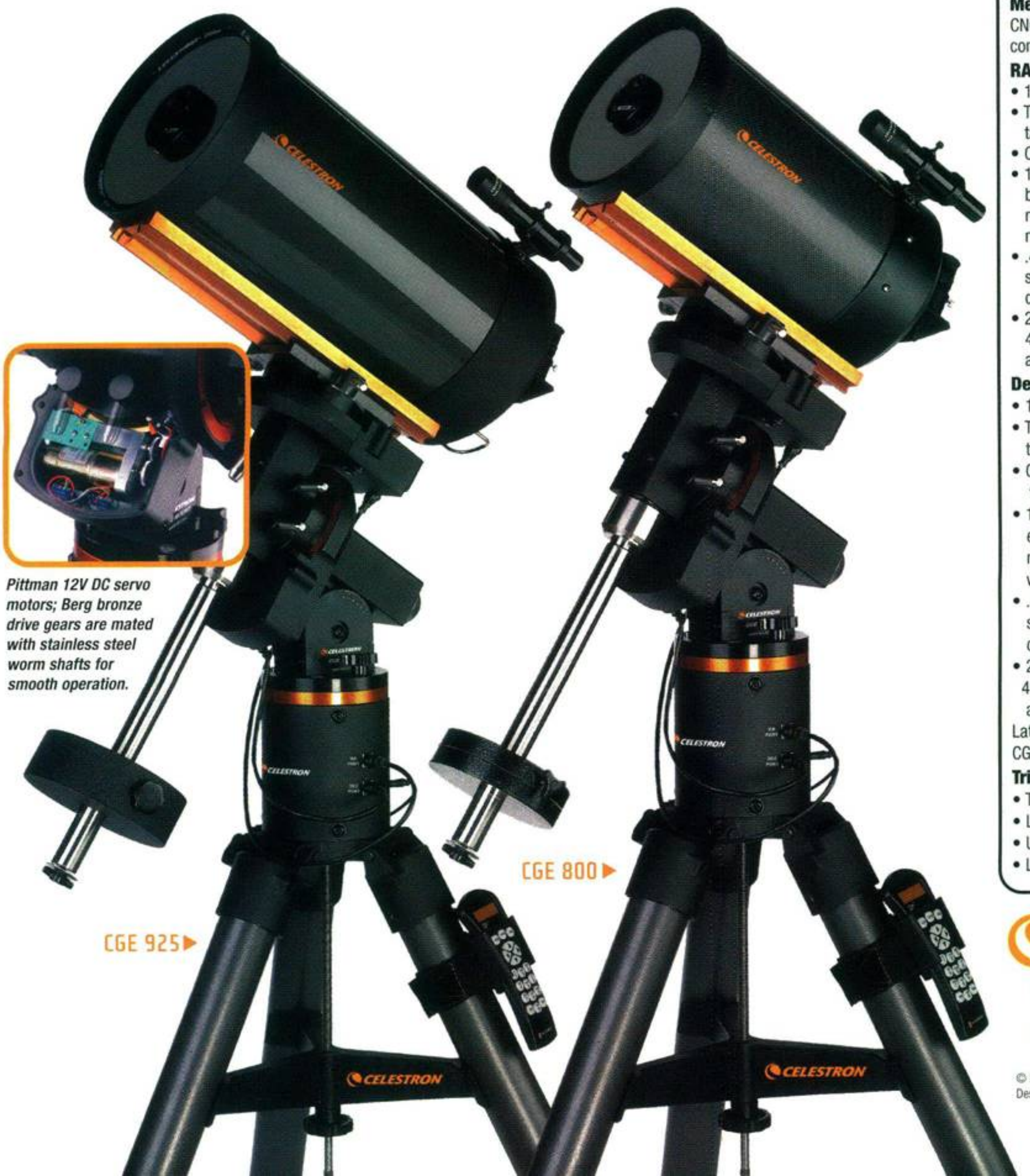
OPTICS	CGE 800	CGE 925	CGE 1100	CGE 1400
Focal length	2032mm; f/10	2350mm; f/10	2800mm; f/10	3910mm; f/11
Secondary Obstruction	2.7"	3.35"	3.75"	4.5"
Resolution (Rayleigh)	.68 arcseconds	.59 arcseconds	.50 arcseconds	.39 arcseconds
Coatings	StarBright®	StarBright®	StarBright®	StarBright®
Optical Tube	Carbon Fiber	Aluminum	Carbon Fiber	Aluminum
Fastar Compatible	Yes; f/1.95	No	Yes; f/2	Yes; f/2.1

STD. ACCESSORIES	CGE 800	CGE 925	CGE 1100	CGE 1400
Eyepiece	25mm Plössl	25mm Plössl	40mm Plössl	2" 40mm Barrel
Star Diagonal	Prism Diagonal	Prism Diagonal	Prism Diagonal	2" Mirror Diag. with $1^{1/4}$" Adapter
Finderscope	6x30	6x30	9x50	9x50
Power Supply	Car Battery Adapter	Car Battery Adapter	Car Battery Adapter	Car Battery Adapter
Counter Weights	1-11lb.	1-25lb.	1-25lb.	2-25lb.



Pittman 12V DC servo motors; Berg bronze drive gears are mated with stainless steel worm shafts for smooth operation.

PRICING

CGE Computerized Mount (#91524):
$2999 + $95 Shipping & Handling
CGE 800 (#11058):
$3499 + $105 Shipping & Handling
CGE 925 (#11059):
$3799 + $145 Shipping & Handling
CGE 1100 (#11061):
$4149 + $245 Shipping & Handling
CGE 1400 (#11063):
$5799 + $295 Shipping & Handling

Optional Accessories:

- 12V DC Rechargeable Power Supply (#18774)
- 2"-70° Apparent Field, Axiom Eyepieces
- Reducer Corrector; f/6.3 (#94175)
- CN16 GPS Accessory (#93963)

Specifications

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400 User defined objects
Hibernate — Maintains alignment even while powered down
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Permanent programmable PEC — Corrects periodic tracking errors inherent in all worm drives
Smooth ramping of slew motors to reduce wear on drive train

Electronics

Home sensors on RA and Dec axes
Real time clock
Fail safe slew limit switches in RA
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Encoder resolution: .11 arcseconds

Mechanics

CNC machined aluminum and stainless steel components

RA axis

- 1" solid ground stainless steel shaft
- Two Preloaded .9835" I.D. x 2.047" O.D. tapered roller bearing
- One 4.724" O.D. x 3.543" I.D. thrust bearing
- 180 tooth, 5.625" diameter enveloping bronze gear preloaded to maintain gear mesh while clutch tension varies, manufactured to AGMA 10 quality.
- .4375" diameter precision 303 stainless steel worm, manufactured to AGMA 10 quality
- 2 point RA clutch system pre-loading a 4.65" stainless steel disk for no-slip drive and pointing precision

Declination axis

- 1" solid ground stainless steel shaft
- Two Pre-loaded .9835" I.D. x 2.047" O.D. tapered roller bearings
- One 3.250" O.D. x 2.500" I.D. thrust bearing
- 180 tooth, 5.625" diameter enveloping bronze gear preloaded to maintain gear mesh while clutch tension varies, manufactured to AGMA 10 quality.
- .4375" diameter precision 303 stainless steel worm, manufactured to AGMA 10 quality
- 2 point Dec clutch system pre-loading a 4.65" stainless steel disk for no-slip drive and pointing precision

Latitude Range: 10° to 60°
CGE Maximum Payload: 65 lbs.

Tripod

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{Astronomy magazine

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Meade LX200GPS Schmidt-Cassegrains set the world standard for serious telescopes, with advanced technology, legendary diffraction-limited optical systems and uncanny 1-arcminute high-precision pointing in GO TO mode.

MEADE
LX200GPS

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Meade 8" LX200GPS Schmidt-Cassegrain–

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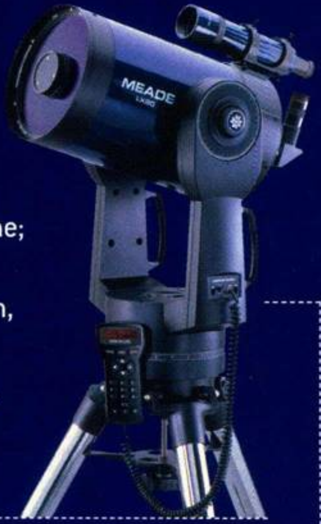

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Third Prize

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Fourth Prize

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Meade ETX-90EC with Autostar–

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Five Awarded
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STARTER KIT

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Use your computer to explore and navigate the moon like an expert.

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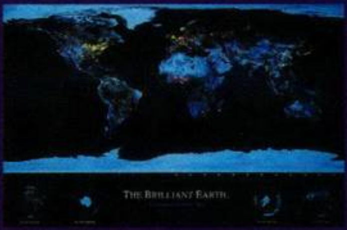

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www.astronomy.com
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No Purchase Necessary. The official start date for the *Astronomy* 30th Anniversary Sweepstakes is April 28, 2003. Official entry forms are bound in the June, July and August 2003 issues of *Astronomy*. The *Astronomy* 30th Anniversary Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependants and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies, and participating sponsors are not eligible to participate.

Sweepstakes Entry. To enter, complete and mail the official entry form or a postcard with name, address, city, state or province, zip and telephone number on a postcard and sent it to: *Astronomy* 30th Anniversary Sweepstakes, P.O. Box 378, Waukesha, WI 53187-0378. Or enter online at www.astronomy.com by filling in the Online Entry form and hitting the SEND key. The Online Entry form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for the *Astronomy* 30th Anniversary Sweepstakes is August 8, 2003, and all entries must be transmitted or postmarked no later than that date.

Prizes and Odds of Winning. One drawing will be held on or about August 29, 2003, for the following awards: One Grand Prize consisting of a Meade 10" LX200GPS telescope (retail value $2,995.00). One First Prize consisting of a Meade 8" LX200GPS telescope (retail value $2,495.00). One Second Prize consisting of a Meade 8" LX90 telescope (retail value $1,695.00). One Third Prize consisting of a Meade ETX-125EC with Autostar telescope (retail value $895.00). One Fourth Prize consisting of a Meade ETX-90EC with Autostar telescope (retail value $495.00). One BONUS drawing will also be held on or about August 29, 2003, for the following awards: One First Prize consisting of a Dark Sky Panel Observatory System (retail value $600.00). One Second Prize consisting of a Telescope Carrying Case (retail value $500.00). One Third Prize consisting of a SkyQuest XT8 Dobsonian (retail value $449.00). One Fourth Prize consisting of an Astroscan Wide-Field Telescope with 2 Plossl Eyepieces (retail value $209.00). Five Fifth Prizes consisting of a Celestron Starter Kit (includes a Night Vision Flashlight, Moon Filter, 2x Barlow Lens, Car Battery Adapter and plastic carrying case lined with foam) (retail value $115.95). One Sixth Prize consisting of the Lunar Map Pro 1.5 software (retail value $89.95). One Seventh Prize consisting of a Space Shot poster set (retail value $79.95). One Eighth Prize consisting of the Lunar Map Pro – Basic edition software (retail value $39.95). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for *Astronomy* magazine is 160,226. Sweepstakes void in Quebec and void where prohibited.

Validation and Acceptance. Winners in the *Astronomy* 30th Anniversary Sweepstakes will be selected in a random drawing conducted by an independent judging organization whose decisions are final. Canadian prize awards subject to skill test requirement. By entering the sweepstakes, participants agree to be bound by these official rules and all decisions of the judging organization. Sweepstakes entries void if not legible, not completed in full, not obtained legitimately, or if forged, photocopied, mechanically reproduced, late or tampered with. The potential winners must sign and return an Affidavit of Eligibility, publicity release and Release of Liability within fourteen (14) days of notification. In the event of noncompliance, alternate winners will be randomly drawn. No responsibility is assumed for lost, stolen, misdirected or late entries or notifications. All sweepstakes entries become the property of the sponsor and will not be returned.

Winner's List. For a list of winners, send a stamped, self-addressed envelope to: *Astronomy* 30th Anniversary Sweepstakes Winners List, P.O. Box 1612, Waukesha, WI 53187-1612. Residents of FL, VT and WA may omit stamp. Requests must be received by September 30, 2003. Or check the *Astronomy* Web site (www.astronomy.com) after February 2, 2004.

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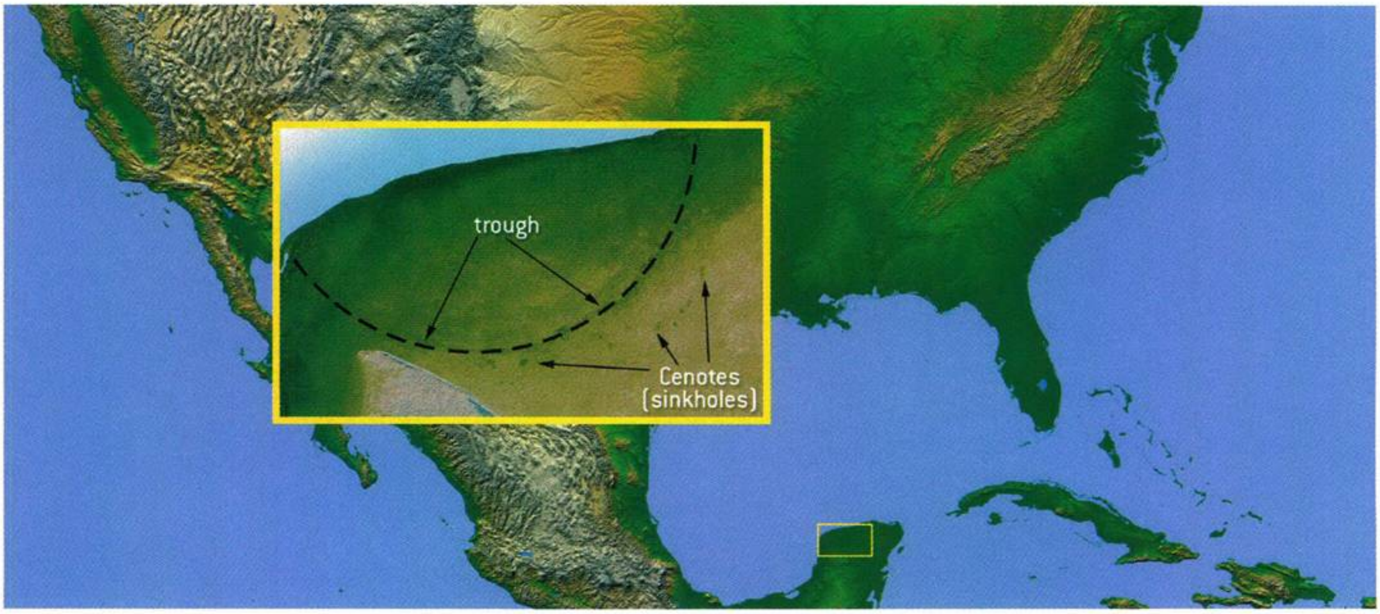
news 07

Read all about it: Gamma ray/supernova link established, asteroid impacts don't trigger volcanoes, galaxy core uncovered, and Prometheus brings NASA new fire.



THE CHICXULUB CRATER on the Yucatan Peninsula appears as subtle surface relief in these Shuttle Radar Topography Mission images. The crater's boundaries are marked by a trough just 10 to 15 feet (3 to 5 m) deep and 3 miles (5 km) wide that is surrounded by sink holes. NASA

ASTEROIDS

Chicxulub revisited

During the 1990s, geologists studying layers of sedimentary rock from locations across the globe noticed a strange layer of iridium. This layer corresponded in age to the death of the dinosaurs and was believed to be linked with their demise. The question that plagued scientists was — Where did all the iridium come from? Early speculations pointed to a celestial visitation of the rocky and violent kind, and in the 1990s scientists pointed to the strange geological formations at Chicxulub, on the Yucatan Peninsula, as the crater associated with the iridium-depositing asteroid that wiped out the dinosaurs.

Now, images obtained during the Shuttle Radar Topography Mission reveal new details in the Chicxulub crater. Along the edge of the crater lies a series of sinkholes that formed when limestone caverns above the crater rim collapsed. Also evident is a semicircular trough 10 to 15 feet (3 to 5 m) deep and 3 miles (5 km) wide. The crater extends into the Gulf.

According to project scientist Michael Kobrick of the Jet Propulsion Laboratory, "Much of the surface expression of Chicxulub is so subtle; if you walked across it you probably wouldn't notice it. That's where the view from space becomes invaluable." — **PAMELA L. GAY**

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33 **Hunting in the Lyman alpha forest**

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EARTH AS A PLANET

How not to erupt

Geophysicists, working in the digital realm of computer models, have struggled to numerically demonstrate how Earth will suffer under the force of impacting asteroids. Several old models suggested that impacts could trigger volcanic eruptions. According to new work by B. A. Ivanov and H. J. Melosh of the Lunar and Planetary Laboratory at the University of Arizona, volcanoes are likely to stay quiet when asteroids attack.

ASTEROIDS TRIGGER VOLCANOES only when they hit areas already near eruption, or when the asteroid is so large it burrows into Earth's mantle. DIGITAL STOCK

To trigger a volcano, an asteroid would need to strike a site already ripe for eruption. "There aren't a lot of hot spots waiting to be hit," says Melosh, "and there aren't a lot of impactors waiting to hit them." It's estimated that an asteroid might hit a hot spot just once every 4 billion years.

That local volcanism isn't a direct outcome of asteroid impacts is apparent in all large craters. "Big craters haven't erased themselves by creating volcanoes," says Melosh. If volcanoes had formed and erupted at impact sites, large craters should be filled with lava. This isn't observed to be the case.

Melosh does note that earthquakes can trigger eruptions in already active volcanoes, and impacts can cause earthquakes. This is impact-assisted volcanism, not induced new eruption. — **P. L. G.**

Cosmology's big three

Despite the normal bickering and wrangling that tend to accompany cosmological meetings, most researchers attending Inflation '03 could agree on one thing. The massive WMAP (or the Wilkinson Microwave Anisotropy Probe) data set released in February 2003 marked a major turning point in the field. It leaves three major questions to dominate future research by modelers and experimentalists alike. Inflation '03 was in Davis, California, in March.

The WMAP observations of variations in the cosmic microwave background (CMB) provide a snapshot of the tiny waves of light that remain from the first seconds of the universe. Those measurements yield exacting constraints for the age of the universe and its flatness, as well as for other variables. However, the CMB data have not answered at least three fundamental questions: What is dark matter? What is dark energy? (The two together make up almost 95 percent of the universe.) And how did inflation, or the millisecond expansion of the universe following the Big Bang, actually happen (if, indeed, it did happen at all)?

The majority of meeting speakers talked about the WMAP data, saying that despite the answers provided, the observations did not signal an end to the field, but a beginning.

"You can't overestimate how important the WMAP data is," says Max Tegmark of the University of Pennsylvania. "Cosmology is no longer in the thin data-starved state it was in a decade ago." The limiting factor now is non-CMB data — supernovae measurements, the Lyman alpha forest, and others.

Several scientists conjectured that the definition brought by WMAP could split the field (although other attendees disagreed). Sir Martin Rees hypothesized that the confirmations of the WMAP data could mark a watershed much like the one that split physics in the 1970s, when advances in quantum mechanics and general relativity divided researchers into theorists and experimentalists.

WISDOM FROM ELDERS passes from Sir Martin Rees (second from right) to Anthony Aguirre, Max Tegmark, and Charles Seife (others, left to right) at Inflation '03. NAOMI LUBICK

Agreeing with Rees, David Spergel of Princeton University said he could see that after WMAP, "the questions and perhaps people will divide" along lines of "the physics of the complex," just after the first second of the universe and onward, and "fundamental physics," or trying to understand the first second.

However, according to Josh Frieman of Fermilab and the University of Chicago, the COBE satellite observations probably had a bigger impact on the field than WMAP, which fine-tuned COBE's earlier observations. Frieman and others do see a future bifurcation of the field but with perhaps more dependency of theorists on data gatherers.

Talks in parallel sessions ranged from almost philosophical discussions of de Sitter Space, string theory, and cyclical universes, to the more experimental, observationally-based work on the Lyman alpha forest and other topics. Most attendees, regardless of field, seemed to agree that cosmology was on the cusp of a major shift in thinking, and that answers would come soon, from particle physics, new observations, and new models based on them. — **NAOMI LUBICK**

DECADAL SURVEY MISSIONS have made it from idea to funding in record time. At the Lunar and Planetary Science Conference in Houston, NASA announced that all five "medium class" missions have been funded as part of the New Frontiers program.

HIGH-ENERGY ASTRONOMY

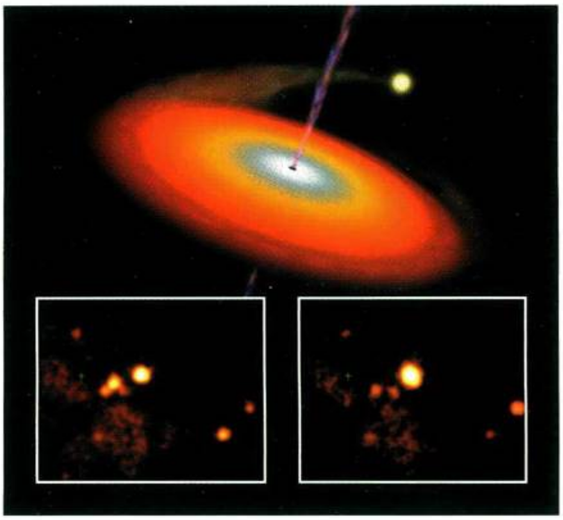
Mid-size black holes

Thanks to the keen x-ray eyes of both NASA's Chandra X-ray Observatory and ESA's XMM-Newton Telescope, astronomers have new evidence for the existence of intermediate-mass black holes. A team of researchers led by Jon Miller of the Harvard-Smithsonian Center for Astrophysics has identified two strong x-ray sources in the spiral galaxy NGC 1313, which lies 10 million light-years away. Miller's team believes it has zeroed in on two mid-size black hole candidates positioned 3,000 and 25,000 light-years from the galaxy's center.

With masses of several hundred suns, black holes in this new class are larger than their miniature stellar cousins, which are only a few times heavier than the Sun. On the other end of the scale, supermassive black holes, at the hearts of galaxies, have anywhere from several million to a billion solar masses.

By measuring the temperature of gas and dust spiraling down the throats of the black holes, astronomers are able to accurately measure the masses of these strange beasts. (Higher temperatures correspond to larger masses.)

Until now, it was unclear if black holes this size could form. "Evidence is mounting that these elusive intermediate-mass black holes really exist," says Miller. "The mystery, really, is *how* they can exist." — **ANDREW FAZEKAS**



MID-SIZE BLACK HOLES feed on stars that wander too close. These black holes have masses from 100 to 500 times the Sun's mass. DAVID A. AGUILAR/HARVARD-SMITHSONIAN CfA INSET: NASA/SAO/CXC

SOLAR SYSTEM

A jovian dozen

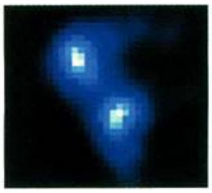
In a burst of discovery, Jupiter's moon count has jumped from 40 to 60. Since March, the International Astronomical Union confirmed the sighting of 20 new satellites orbiting the giant planet. All are tiny — between one and four kilometers wide — with elongated and highly inclined retrograde orbits.

FAINT AND FUZZY, Jupiter's moon S/2003 J1 was imaged on March 4, 2003. S. SHEPPARD/UH

The satellites, labeled S/2003 J1 to J20, were first found by a team led by University of Hawaii astronomers Scott Sheppard and David Jewitt. The researchers used telescopes atop Mauna Kea to discover and follow the new moons. They are currently tracking other candidates. — VANESSA THOMAS

SUPERNOVAE

High-energy connections



SPECIAL SUPERNOVAE create gamma-ray bursts.
CXC/M. WISS/NASA/N. BUTLER ET AL.

Recent observations by the Chandra X-ray Observatory have confirmed that in some cases gamma-ray bursts are associated with supernovae. In a 21-hour observation of the gamma-ray burst GRB020813, Chandra detected the spectral signature of a recent supernova explosion.

"Our observation of GRB020813 supports two of the most important features of the popular supra-nova model for gamma-ray bursts," says astronomer Nathaniel Butler of the Massachusetts Institute of Technology. "An extremely massive star likely exploded less than two months prior to the gamma-ray burst, and the radiation from the gamma-ray burst was beamed into a narrow cone."

The supra-nova model, like a standard supernova model, starts with the collapse of the core of a massive star. This core forms a rapidly spinning black hole that, in supra-nova models, produces a high-energy jet. Some time later, shock waves in the jet trigger the focused beams of gamma and x rays that are observed. — **P. L. G.**

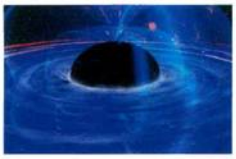
EXTRAGALACTIC ASTRONOMY

Life-giving black holes

Supermassive black holes, considered the grim reapers of the cosmos, may in fact give life as well as take it away. A team of astronomers using the Chandra X-ray Observatory and XMM-Newton satellite found evidence that winds traveling at 40 percent the speed of light carry large amounts of gas away from two quasars.

The quasars are the brilliant cores of galaxies powered by supermassive black holes. Their newfound winds aren't part of the high-speed jets of subatomic particles that shoot from black holes, but come from the surrounding accretion disk.

"The winds we measured imply that as much as a billion Suns' worth of material is blown away over the course of a quasar's lifetime," said team leader George Chartas of Pennsylvania State University. The winds disperse elements, such as hydrogen, carbon, oxygen, and iron into the interstellar medium. — **V. T.**

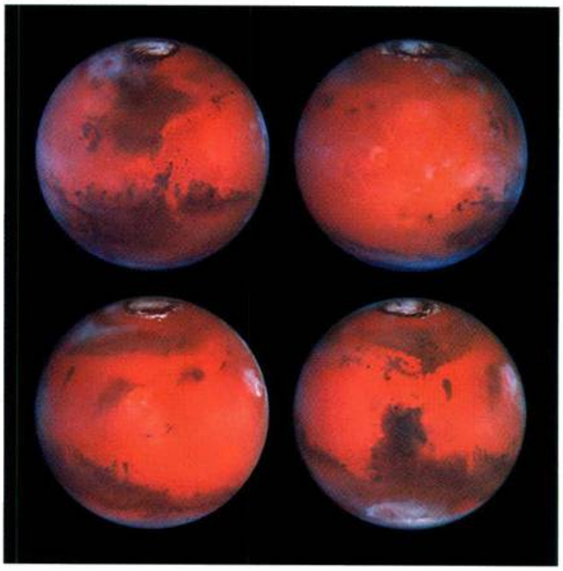


WINDS OFF THE DISKS of material surrounding quasars enrich surrounding space. NASA/DANA BERRY

SETI INSTITUTE ASTRONOMERS used the Arecibo Radio Telescope in Puerto Rico to re-observe 166 sources deemed promising by "SETIahome" software. Initial results show no definitive signal from other civilizations.

SOLAR SYSTEM

Mars: Look now, go now



MANY FACES OF MARS will be visible as Earth orbits past it in the next few months. Martian polar caps are easily discerned in even modest telescopes. HST

On August 27, 2003, Mars and Earth will be separated by a mere 34.9 million miles (55.8 million km). This close approach offers many opportunities for observers and explorers, but to take advantage of them people must act now.

Observationally, amateurs should begin viewing Mars during our approach to the planet, throughout June and July. Early viewing is encouraged for two reasons: It will allow observers to notice changes in angular size and (very slightly) in phases of Mars, and it will train eyes to discern details on the martian surface. With luck, the vast valley systems and icy polar caps will be in clear view come August. As with all observations, however, you need to worry about weather. With Mars, the weather risks include the possibility of martian dust storms hiding the surface from terrestrial view.

The European Space Agency also plans to take advantage of the close approach of Mars to launch its Mars Express exploration mission. This system includes the Beagle 2 lander, which will set down on Mars's Isidis Planitia. At the time this story went to press, Mars Express was scheduled for liftoff in June but had not yet been shipped to the Baikonur Cosmodrome in Kazakhstan for launch. If successful, Mars Express will reach Mars in December 2003, providing ESA a Merry Christmas. — **P. L. G.**

SPACECRAFT

Next Explorer ready

NASA has selected an Earth satellite as one of its next "medium-class" missions in the Explorer program. Titled "Time History of Events and Macroscale Interactions during Substorms" (THEMIS), the project will use five satellites to measure particles and magnetic fields in orbit.

NASA plans to launch THEMIS in 2007. This mission uses flight-proven technology in novel ways to study Earth's space weather.

Data from the THEMIS satellites, combined with ground data, will be used to study the dynamics of space storms that cause aurorae and the mechanisms that transport and explosively release solar wind energy into the space around Earth.

In addition to studying solar substorms, THEMIS will answer critical questions about Earth's radiation belt and how energy in solar wind and in the magnetosphere are coupled.

This mission is not related to the similarly abbreviated Thermal Emission Imaging System (THEMIS) that is now studying Mars. — MATT QUANDT

STARS

Stellar reality

Astronomers using the Very Large Telescope Interferometer to study the Alpha Centauri system have observationally shown that stellar models are a clear fit to reality.

Astronomers measured the disk sizes of Alpha Centauri A and B and combined this data with past observations of the stars' masses and temperatures. "The agreement between the VLTI measurements and the theory is very satisfactory for both stars," says ESO astronomer Pierre Kervalla. "This confirms the validity of the multi-technique approach and . . . we now have a rather complete view of this famous triple system." Alpha Centauri A and B are the largest stars in a triple system that also includes Proxima Centauri. — **P. L. G.**

ALPHA CENTAURI A AND B appear as a single glow in this ESO 1-meter Schmidt Telescope image. ESO

HUBBLE HERITAGE IMAGE

New tricks for an old galaxy

A burst of star formation just 26 to 31 million years ago is responsible for the formation of a giant star cluster at the center of NGC 1705, as well as for many of the young stars on its outskirts. Dwarf irregular galaxies like NGC 1705 were among the first galaxies to collapse and start forming stars in the early universe. Later, through hierarchical clustering, dwarf galaxies combined to form giant spiral and elliptical galaxies like our own.

COOL RED STARS dot the fringes of NGC 1705, with hot young blue stars concentrated at the center. NASA/ESA

At 17 million light-years away and 13.5 billion years old, NGC 1705 displays traits similar to those of very young galaxies but is nearer and easier to study. It provides astronomers a wealth of data on star and galaxy formation. — **LAURA WILLIAMS**

Prometheus provides NASA new fire

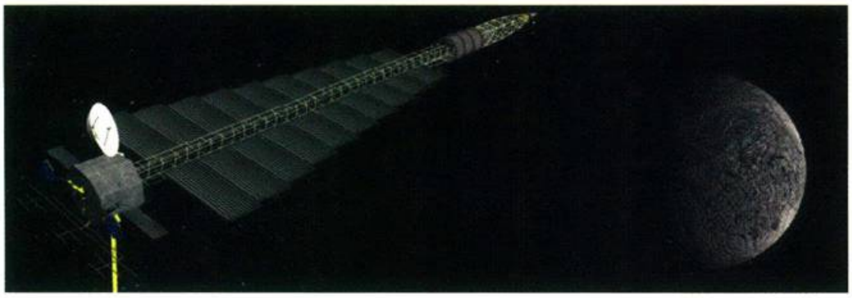
In the shadowy gloom following the Columbia tragedy, NASA officials have been muted in their boasting about plans for advanced unmanned space missions. One positive theme that has quietly emerged comes from their excitement about the space nuclear power initiative, named Project Prometheus, and the flagship mission to exploit it, the Jupiter Icy Moon Orbiter (JIMO for short).

NASA chief Sean O'Keefe has championed the development of nuclear power sources for deep-space vehicles, for applications ranging from electric propulsion (ion drive) to instrumentation. "With the new technology, where we go next will only be limited by our imagination," says O'Keefe. "The laws of physics are the only things controlling how fast we go anywhere. So until we beat the technical limitations . . . you basically end up arguing about fantasy missions."

Past spacecraft had to perform all tasks with just a light bulb's worth of energy. This limited the number of instruments that could be used and the amount of data that could be transmitted at one time. With Prometheus's orders-of-magnitude improvements in available power, NASA engineers have designed a Jupiter exploration mission for the end of this decade that will spend many years examining the gas giant and its moons in unprecedented detail. In particular, it will study the possible subsurface liquid water oceans on Europa, Ganymede, and Callisto. Originally called "Jupiter Tour," it later became JIMO, and is expected to be the prototype for future spacecraft sent farther out toward the edge of the solar system in coming decades.

According to Colleen Hartman, NASA's Solar System Exploration Division Director, JIMO's 100-kilowatt reactor will revolutionize science operations and open the opportunity for high-powered instruments such as ice-penetrating radar and massive data rates. "We've been running on 100-watt bulbs, and this is stadium lighting all of a sudden," she says.

NASA scientists at the 34th Lunar and Planetary Sciences Conference did describe "plutonium problems" for their smaller space power units, called radioisotope thermal generators (used on small spacecraft since the 1960s). The problem is that the U.S. shut down its plutonium-238 production facility ten years ago for environmental reasons. It would take five years to re-start an independent U.S. production capability. For now, we have to buy this material overseas, and Russia is the obvious source. So far the Russians have sold NASA $12 million worth of nuclear fuel, and last January the U.S. Department of Energy signed another $23 million contract with a Russian firm to supply plutonium dioxide pellets. Delivery will start in about a year and will continue for five years. **— JAMES OBERG**

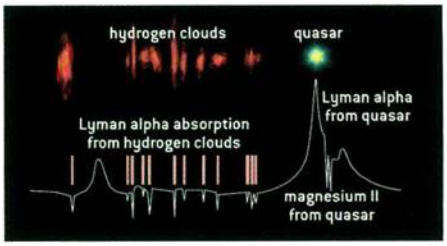


JIMO, FUELED BY PROMETHEUS, will explore Jupiter and its moons with unprecedented power and sensitivity. This mission will open a new era of solar system exploration. NASA

COSMOLOGY

Hunting in the forest

The Lyman alpha "forest" may be the next place to do some detection work in order to determine details of the early universe's history. The forest appears in spectra of distant quasars and is composed of dark bands created by intervening hydrogen clouds that absorb light from a quasar. Astronomers are carefully hunting for new information in the chaotic forest of these absorption lines.



THE LYMAN ALPHA FOREST comes from hydrogen clouds absorbing quasar light. Each line's wavelength corresponds to a cloud's redshift. P.L.G.

Uros Seljak, of Princeton University, and his colleagues have been trying to use the Lyman alpha forest to find evidence of dark matter. Their results hint at deviations from the steeply curved mass distribution that seems to describe the universe best. Such results might seriously challenge current models.

Other researchers, such as Lam Hui of Fermilab, have not found such evidence in their work on the Lyman alpha forest, but they are open to considering Seljak and his coworkers' results.

"There are hints that something unexpected is there, but no conclusive evidence yet," says Lyman Page of Princeton University.

Page, Hui, and others have called the Lyman alpha forest a "lever arm" that will give greater strength to other observations. "It physically probes the universe at much smaller scales than cosmic microwave background observations," Page says. The future Planck satellites, in conjunction with further observations by WMAP, hold promise for future snooping in the forest. **— N. L.**

Inventory Clearance Sale Continues

"Your telescopes are such a great deal, I feel like I'm taking advantage of you," one customer recently told Larry Hardin.

"Please take advantage!" was Hardin's reply. "I've got some of the best telescope buys in the industry."

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Most experienced amateur astronomers believe that a great place for the beginner to start is with a six or eight-inch scope. But even veteran amateur astronomers have purchased these smaller scopes for themselves. "Their evening viewing usually starts with our six or eight-inch Deep Space Hunters. The next thing you know, you can't pull them away from the eyepiece," observes Hardin. "It's really amazing just how good these scopes are."

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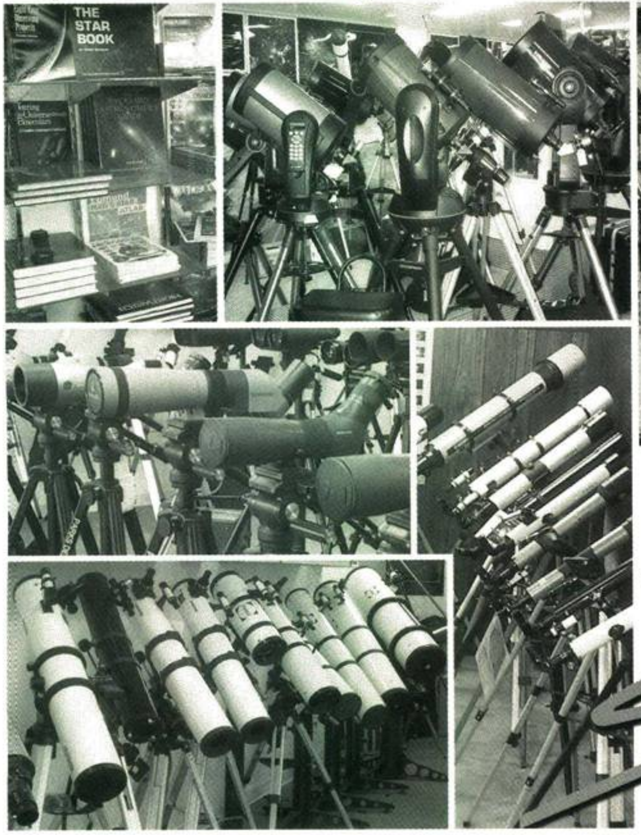

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Goldilocks

Greenhouse gases allow our world to sustain life, but scientists struggle over which gas — carbon dioxide or methane — dominates the atmospheres of Venus, Mars, and Earth.

/// NAOMI LUBICK

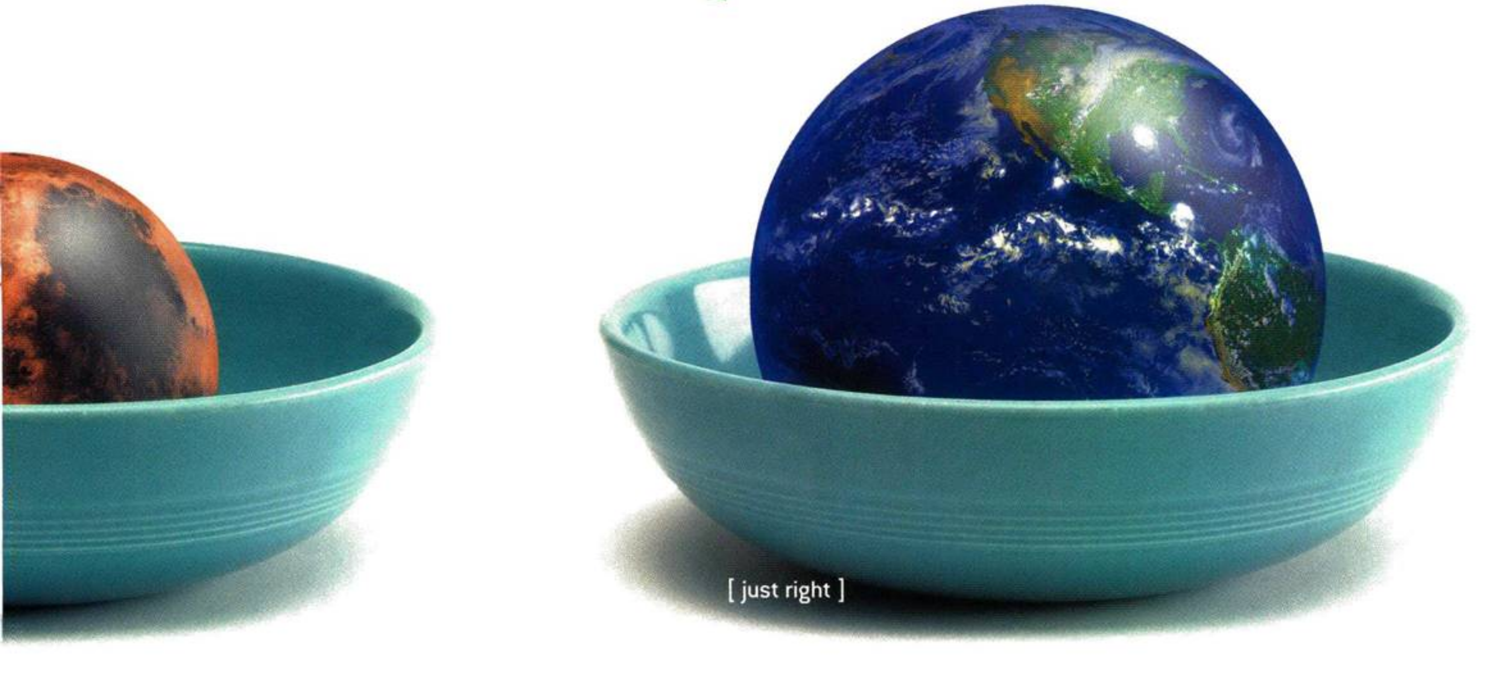
[too hot]
[too cold]

The idea of greenhouse gases — carbon dioxide, chlorofluorocarbons, Freon, methane — brings to mind images of carbon-based pollutants billowing from industrial smokestacks, holes in the ozone, snowless winters, and rising ocean levels. While these gases may be negatively impacting life today, historically they may have been responsible for creating an Earth capable of sustaining life.

For the past several decades, carbon dioxide (CO_2) has dominated the atmospheric models for Earth and its nearby rocky neighbors, Mars and Venus. Carbon dioxide has even been used to explain how our Goldilocks Earth became a habitable planet, while too cold Mars and too hot Venus did not. Recently, however, researchers have begun to reassess the prominence of carbon dioxide in the development of the early atmosphere of our planet. Atmospheric chemists and geophysicists are now turning to an idea that fell out of vogue in the 1970s: the dominance of methane (CH_4) in the early Earth's atmosphere and perhaps in the atmosphere of Mars as well. This smelly gas, more often associated with cows than with evolution, is coming back into style as the molecule of choice for making warm, moist environments suitable for life as we know it.

Methane's stardom in this planetary fairy tale began in the 1950s, in a paper by Carl Sagan and his coworkers, who pro-

& the three planets



VENUS: JPL/NASA / MARS: USGS / EARTH: NASA

posed that the gas could have made the temperature of our planet "just right." Initial models of carbon dioxide-based environments contradicted Sagan's work. But from those models, some of the same researchers are now coming to believe that methane may have dominated in creating Earth's modern atmosphere. Along the way, the same gases that make this planet livable failed to warm Mars and overheated Venus, making Earth the only local world just right for life.

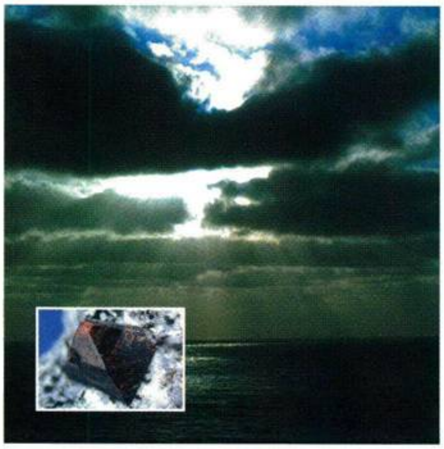
Once upon a time

Life on Earth formed from carbon-based organic molecules — the same carbon, hydrogen, and oxygen atoms that make up greenhouse gases also make up our bodies. In the 1950s, University of Chicago graduate student Stanley Miller suggested that the early Earth had an atmosphere of methane and ammonia (NH_3), and that organic molecules formed in this environment could be the precursors of life. Carl Sagan and his coworkers took this one step further and proposed that atmospheric methane could maintain a warm, moist environment conducive to sustaining that life.

In the 1970s, many scientists rejected these ideas; methane's atmospheric life expectancy was considered too short to impact the environment. In sunlight, methane is broken down by hydroxyl radicals (see "Got methane?," page 39). This process, called photolysis, destroys methane in oxygenated environments.

While methane absorbs heat about 30 times more efficiently than carbon dioxide, researchers at the time thought that its transitory nature caused methane to have less of an overall effect than long-lasting, atmospheric carbon dioxide. In today's oxygen-rich atmosphere, methane molecules survive for only about 10 years. In the early Earth's atmosphere, which had less oxygen, methane molecules were estimated to last for about 300 years, but geologically, that's still a short time. Once carbon dioxide is in the atmosphere, it's stable and it's there to stay. Methane naysayers pointed to Venus and Mars, and their modern carbon dioxide atmospheres, and declared carbon dioxide to be the more important molecule.

RAIN WASHES THE ATMOSPHERE of carbon dioxide and locks it in minerals, such as siderite (inset). P. L. GAY. INSET: D. MERKE (PROTONMINERALS.COM)



AUSTRALIAN ZIRCONS FORMED IN LIQUID WATER 4.4 billion years ago. This requires greenhouse heating. ARTTODAY.COM. INSET: D. MERKE (PROTONMINERALS.COM)

OXIDIZED IRON BANDS in the geologic record mark the transition to an oxygenated atmosphere. G. GROSS (GSC)

Where has all the carbon gone?

To prove the dominance of carbon dioxide, atmospheric scientists sought to recreate the atmospheric history of Earth using computer models. In the mid-1980s, James Kasting, a professor at Pennsylvania State University, presented pioneering work on carbon dioxide-based greenhouse atmospheres for Mars and Earth. These models took into account the chemical and temperature evolution of our planet and sought to recreate today's atmosphere via millions of years of evolution.

While Kasting's initial models were promising, problems arose over time that couldn't be ignored. Kasting and other atmospheric modelers were unable to synthesize an atmosphere that maintained temperatures above the freezing point of water without introducing massive amounts of carbon dioxide into their model atmospheres. Pumping the levels of atmospheric carbon dioxide extremely high, however, triggers feedback loops that cause it to condense out of the atmosphere in rain.

While carbon dioxide is chemically stable in the atmosphere, it isn't necessarily permanent. Carbon dioxide can be washed out of the atmosphere in rain, and increasing the atmospheric carbon dioxide level causes it to rain more, which then increases the wash-out rate. Rainwater carries carbon dioxide through the geologic cycle until it gets locked into sedimentary deposits called carbonates. Through erosion and plate tectonics — the motion of Earth's crustal plates — this carbon dioxide returns very slowly to the atmosphere. Since this feedback loop can remove carbon dioxide from the atmosphere faster than the rate Earth can release it, any past peaks in atmospheric carbon dioxide should still be locked away in sedimentary deposits, or at least have left some kind of signal in the geologic record.

Alex Pavlov, a colleague of Kasting, has thought hard about carbon dioxide feedback loops. "Climate models predict 20 percent carbon dioxide in the atmosphere to keep surface temperatures high enough [for liquid water]," says Pavlov, who is now a researcher at the University of Colorado. Today, Earth's atmosphere is 78.1 percent nitrogen, 20.9 percent oxygen, 0.9 percent argon, about 360 parts per million (ppm) carbon dioxide, and slightly less than 2 ppm methane. This implies that if the dominant greenhouse gas in the early atmosphere was carbon dioxide, then our atmosphere dramatically evolved from 20 percent carbon dioxide to essentially no carbon dioxide.

If these models are correct, the currently unobserved carbon dioxide should be trapped in the geologic record in the form of siderite — iron carbonate — deposits. "You would expect . . . a lot of siderite," Pavlov continues. But it hasn't been found in ancient soils, leading researchers to hypothesize that there wasn't enough carbon dioxide. This geologic proof has led researchers to think some other gas might be responsible for warming Earth in its youth.

Pavlov started thinking about methane as the alternative gas while starting his career in Russia at a time when the gas was not in vogue. "When I came here [to work with Kasting at Penn State], Jim was thinking about it — there are problems with carbon dioxide. It was at the limit of its applicability." Together, the two scientists would look for new solutions based on an old idea.

The too faint Sun

Just as Sagan was behind the initial idea of methane as a driving atmospheric gas, he may also be behind its return to popularity. According to Kasting, his personal change in perspective was triggered by

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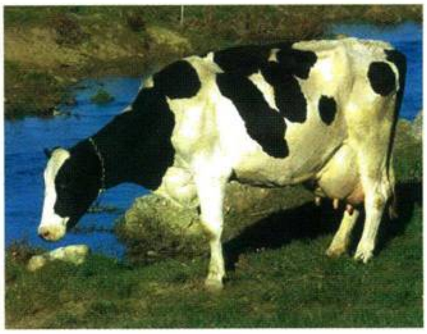
NAOMI LUBICK's *training as a geologist has led her to think on geologic time scales, but as a freelance writer based in California, she likes to think about life on other planets.*

/// GOT METHANE?

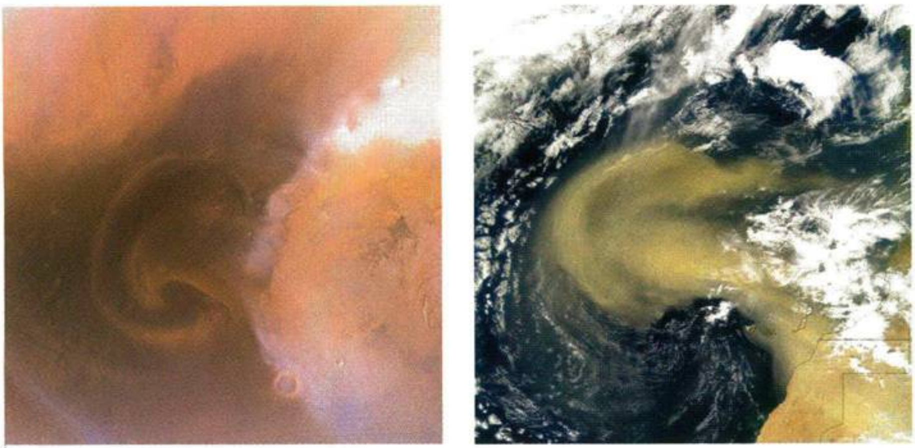
ATMOSPHERIC METHANE (CH_4) is luckily in short supply in our modern, oxygenated atmosphere. This noxious gas is an effective insulator and in large amounts can lead to significant planetary heating. While an increase in Earth's average temperature would be devastating to modern life, methane played the role of the great protector for methanogens and other life-forms struggling to survive when the Sun was still younger and fainter. In fact, the sudden destruction of atmospheric methane may have led to a terrible ice age and mass extinctions when Earth's atmosphere became oxygenated, destroying the methane, 2.2 to 2.45 billion years ago.

In a non-polluted, oxygenated atmosphere, hydroxyl radicals (OH) react with methane and, via by-products that include formaldehyde ($HCHO$), also react with oxygen (O_2) and hydrogen dioxide (HO_2) to eventually form carbon dioxide (CO_2). On average, methane molecules can survive for no more than 10 years before oxygen-wielding molecules destroy them. In polluted environments this process is accelerated by nitric oxide (NO).

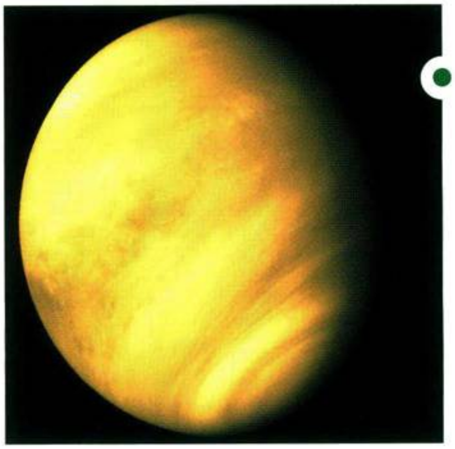
On Earth, the primary methane sources are ruminating animals (e.g., cows) and marsh gases. Man-made methane emissions from gas leaks, fossil fuel production, and landfills are also significant. — *Pamela L. Gay*



MAJOR METHANE PRODUCERS include swamps, rice fields, and ruminating animals such as cows. ARTTODAY.COM



DUST STORMS ON MARS AND EARTH grow from the same atmospheric physics. Understanding our world helps us understand others and allows for the creation of atmospheric models that incorporate features we haven't directly measured except on Earth. MARS: NASA/JPL/MSSS EARTH: SEAWIFS (NASA/GSFC)



VENUS'S CARBON DIOXIDE ATMOSPHERE adds 500° F to its average temperature. No methane was required to overheat this world. JPL/NASA

data published in a 1997 *Science* article by Sagan and colleague Christopher Chyba. This paper was responsible for reviving the debate about how to warm Earth and Mars with a faint, young Sun.

In 1972, Sagan and George Mullen first wrote about the Faint Young Sun problem in another article in *Science.* When the rocky planets in our solar system began forming, they wrote, the Sun's luminosity was about 30 percent weaker than it is now. With such a low level of sunlight, water could not have remained liquid on any of the planets. Nevertheless, there is evidence that zircon crystals formed 4.4 billion years ago in liquid water on what is now Australia. The existence of those crystals mandates an early terrestrial greenhouse atmosphere capable of increasing the temperature enough to keep water liquid. At the same time, the lack of a siderite-rich geologic record indicates that carbon dioxide couldn't have been the primary temperature-raising gas.

In reexamining how to raise the young Earth's temperature with the added problem of a too-faint Sun, atmospheric scientists reevaluated how long methane was able to survive. Models by Pavlov showed that in an early atmosphere without much oxygen, a methane molecule would escape photolysis for 10,000 times longer than in earlier, oxygenated models. Methane may even have persisted on the order of 10,000 years in an ancient oxygenless (anoxic) atmosphere on Earth. Moreover, fresh rock — young solidifying crust — would absorb much of the carbon dioxide present in the atmosphere, leaving methane to take the lead heating our world.

Metabolizing methane

A warm, wet planet without much oxygen would be very convenient for life if that life were composed mostly of methanogens. These microbes synthesize carbon dioxide and hydrogen to make methane and water — which fits nicely into a methane-dominant scenario.

Kasting says he also likes a methane-dominated atmosphere on Earth because it works for the "Snowball Earth" scenario. Our planet may have been completely glaciated several times in its history, with ice to the equator, causing it to resemble a giant, orbiting snowball. According to Paul Hoffman and Dan Schrag, two very vocal proponents of the snowball theory, a methane greenhouse may have been the key to getting Earth out of that icy state. For Kasting, this may be the final kicker — if life were pri-

This is a "man-bites-dog" story. If the only source of methane is biological, then liquid water on an early Mars was due to the presence of life.

THE AMOUNT OF CRATERING on a planet is an indicator of how frequently its surface is renewed through plate tectonics and weathering. Mars (left) and Venus (right) appear to have been geologically active until recently, although Mars shows significantly more cratering than Earth. Earth's surface (center) is still being constantly refreshed, with visible craters showing significant erosion. MARS: NASA/JPL/MSSS, EARTH: NASA/LPI, VENUS: JPL/NASA

marily made of methanogens, then Earth's early life-forms may have maintained a methane-based atmosphere for a long time through their own biological, methane-producing chemistry.

One other factor helps methane avoid destruction: It forms light-blocking haze.

What researchers did not understand when they first rejected methane as a larger component in early atmospheres, says Chris McKay, an astrobiologist at NASA-Ames, "was that methane could form a haze that could protect it [from photolysis]." Recent observations of Titan, Saturn's methane-rich satellite, make it clear that an organic haze created from methane molecules tops its atmosphere. This haze shields methane in the layers below from destructive sunlight.

Hypothetically, Pavlov says, methane molecules at the top of the early Earth's atmosphere could have created long, organic chains that would collide and grow, forming a similar protective haze. These chains could also, Pavlov says, "make it to sediments and be utilized by the biota as a food source." Or perhaps these chains are the origins of life, as Stanley Miller suggested decades ago.

But how did our world evolve from a methane-based ecology to one dominated by oxygen-requiring life forms? About 2.2 to 2.45 billion years ago, Earth's geologic record shows a sudden jump to an oxygen-rich atmosphere. So-called red beds deposited in that period show that enough oxygen accumulated to oxidize iron. The change to an oxygen-rich environment may have been driven by a variety of different sources. One theory suggests that cyanobacteria — bacteria that give off oxygen — increased in number to the point that they could saturate our atmosphere with oxygen. With the rise of oxygen, no matter the source, methane-producing microbes and atmospheric methane were all but wiped out.

Meanwhile, on Venus and Mars

But what happened on Venus and Mars? Why is one too hot and the other too cold to sustain life? The answer lies in the initial conditions at the birth of each world. Unfortunately, we don't know enough about the geologic record on either of these planets to say for certain what happened in their past.

What we know of their current conditions shows that the picture is simplest for Venus. McKay says Venus never needed methane to get too warm. Venus seems to have suffered a runaway greenhouse effect based on carbon dioxide. Whatever water may have been present on this green planet remained in its atmosphere instead of raining out. Today, greenhouse gases add more than 500° F to Venus's surface temperature over and above what the Sun's heat provides.

Mars is more complicated. It is possible that Mars may once have had a more temperate climate. Many scientists point to dramatic canyons and scarps on the martian surface and say that liquid water must once have flowed freely on the Red Planet. Owen Brian Toon, from the University of Colorado, and his coworkers, however, suggest that Mars's atmosphere was never warm enough to maintain liquid water on its surface and allow for these features to be created via seasonal rainfall. Rather, their work shows that impacts from meteors may have melted martian ice, allowing transitory rainfall to create its apparently water-carved features.

So, perhaps Mars doesn't require rain from a thicker atmosphere. But if it did have an atmosphere with methane (and methanogens), Mars would have been warm enough to retain liquid water.

McKay calls this a "man-bites-dog" story. If the only source of methane is biological, then liquid water on early Mars was due to the presence of life. "Biology allows for liquid water [via methane]," McKay says. "The dog-bites-man is that liquid water allows for life."

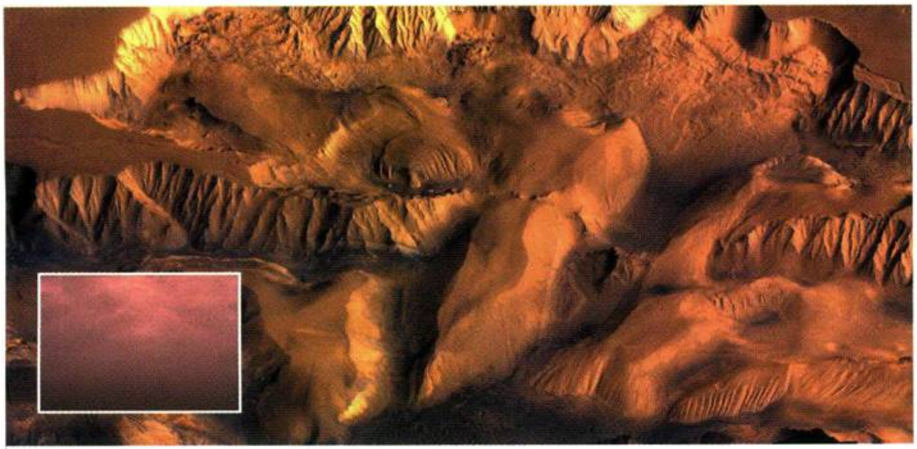
These arguments all factor into the discussion of habitable planets. The Goldilocks paradox asks the basic question: Why is Mars too cold, Venus too hot, and Earth just right for water and life? The basic answer is that Earth was in just the right place — not too close and not too far from the Sun. But that is too simplistic. When considering only its distance from the Sun, even Earth would have been at temperatures below the freezing point of water in its early days because of the Young Faint Sun problem.

If distance isn't enough, a second parameter must be responsible. According to Michael Rampino of New York University, a planet's distance from the Sun and its size together determine if it will be habitable. Rampino uses Earth's Moon as his favorite illustration: The Moon, which is the same distance from the Sun as Earth, is not habitable because it is too small to hold an atmosphere.

"As a planet grows, heat is locked inside," says Rampino. Planets start out hot and that heat powers plate tectonics. Plate tectonics renews Earth's crust through cyclical creation and destruction. At spreading ridges between plates (usually mid-ocean), magma wells to the surface and cools into crust. Old crust is destroyed by subduction, which swallows and transforms plates into the molten-rock mantle. During degassing, greenhouse gases (including carbon dioxide) trapped in the crust escape through volcanoes and at tectonic spreading centers. These spreading centers are often teeming with life, even in the otherwise hostile environment of the deep ocean floor.

"If a planet is too small," Rampino says, "the heat builds up and then escapes to space." Without a hot, liquid, planetary interior, plate tectonics ends and so does the carbon cycle. The crust weathers and ages, and the atmosphere condenses as the entire world cools and dies.

On these three rocky planets, the crust's freshness can be translated from the amount of visible cratering. A myriad of Moon pictures, Mars images from Mariner, as well as Venera images of Venus have allowed Earth-bound geologists and astronomers to assess the ages of these worlds' surfaces. Mars (and the Moon) seemingly had plate tectonics until recently, as is evidenced by fresh crust on its surface and markings of meteorite impacts. Evidence for plate tectonics is unclear on Venus, despite plenty of volcanism. For now, it appears these bodies are tectonically dead.



THE MARTIAN SKIES [inset] once deluged the Red Planet's surface with water, carving detailed features. Whether a temperate climate or transitory melting from asteroid impacts mediated these rainstorms is unknown. USGS / NASA INSET: UNIVERSITY OF ARIZONA

VOLCANIC ERUPTIONS release carbon dioxide and other gases into the atmosphere, completing the carbon cycle. KEN RUBIN

Happily ever after?

At their inceptions, Mars, Venus, and Earth were much different from today. Perhaps warmer, they received less sunlight and had unknown continental topographies. Even the amount of cloud formation may have been different. With so many unknowns, scientists must base their atmospheric simulations on best-guesses of initial planetary conditions.

Was Mars once warm, or did asteroid impacts cause temporary rainfall to carve its surface? Differing models lead to similar modern-day results. Exploration of the martian geologic record may someday answer that question, but for now, Mars keeps her secrets to herself.

On Earth, we look up to the sky, as well as down through the sedimentary layers, for answers. Pavlov notes that climate models in use today are tuned to the current atmosphere on Earth. "[The] numerous climate feedbacks indeed work at present," Pavlov says, "but we have no idea how they were supposed to work in ancient times."

"Methane is on the rise in terms of explaining a number of things in geology," Rampino says, including climate change on our own planet. "Carbon dioxide was always the favorite. Methane was ignored. If it can be stable, then it provides a very powerful greenhouse gas."

In a past without oxygen, methane may have been stable. Without evidence for past peaks in carbon dioxide levels, methane is becoming the gas of choice for modeling a warm, moist atmosphere for Earth and perhaps for Mars as well.

But models are not truth, says McKay, and have proven challenging even for our own planet, where geologists actually can field-check them. "I've been in this field for 15 years, and I've seen it go back and forth," he says, with regard to methane's role in the evolution of Earth's atmosphere. "The moral of the story is that we don't really know."

And that is what keeps science interesting: the constant struggle to develop, and sometimes redevelop, theories that answer the questions of origins and evolution. Until scientists can field-check the geology on our neighboring planets, models will have to suffice in solving the Goldilocks paradox and the methane versus carbon dioxide debate.

To learn more about atmospheres visit http://www.astronomy.com/toc

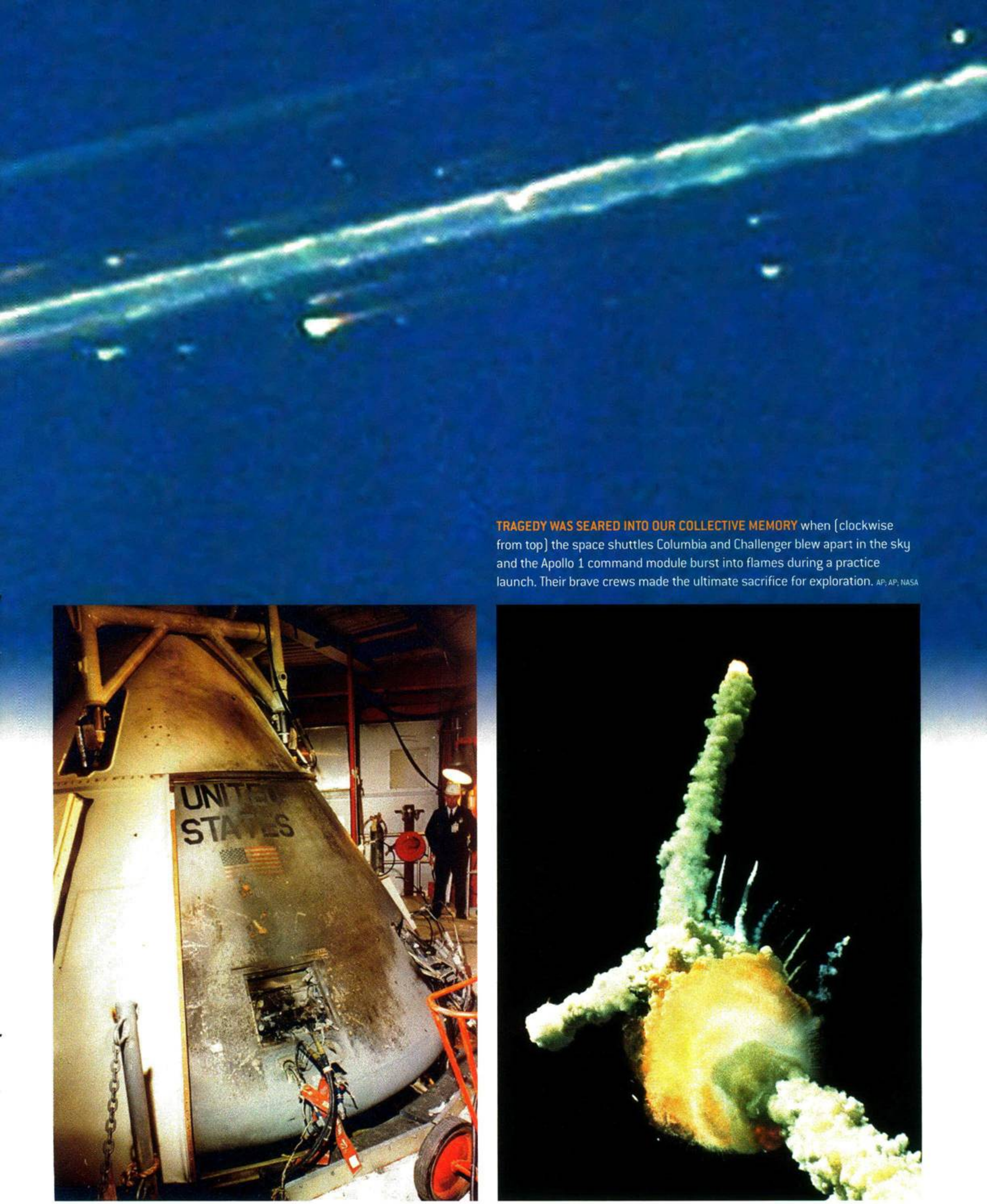
Trial by FIRE

Some of the hardest lessons of the space age have come at the highest price. Why we must learn to live with risk. /// BOB BERMAN

The great ship Columbia had suddenly become a bolide, a daytime meteor. People in five states stared in horror as hurtling aluminum fragments, burning like Roman candles, decelerated from Mach 18. NASA personnel were shocked. But not completely surprised.

A week before the tragedy, I hosted a radio show commemorating the last shuttle disaster in which I quoted insider warnings that the shuttle was far more dangerous than commonly believed. In the show, experts pegged the per-flight risk of a catastrophic failure at nearly the same 1-in-100 or so odds that analysts had given in 1988, when the fleet resumed flying after the Challenger tragedy.

The point: The shuttle is not a safe machine. It never will be. And the odds won't change very much when flights begin again. Too many things can go wrong despite engineers' best efforts. Everyone knows this now, of course, and we'll cross our fingers each time future



TRAGEDY WAS SEARED INTO OUR COLLECTIVE MEMORY when (clockwise from top) the space shuttles Columbia and Challenger blew apart in the sky and the Apollo 1 command module burst into flames during a practice launch. Their brave crews made the ultimate sacrifice for exploration. AP; AP; NASA

COLD WAR HYSTERIA led to the rushed test-launch of a ballistic missile at the Soviet Union's Baikonur Cosmodrome that killed at least 92 people. With the fuel tanks filled and leaking, the rocket's second stage accidentally ignited during launch preparations. VIDEOCOSMOS

SPLASHDOWN came not with relief but terror for Gus Grissom after his 15 minutes in space — the hatch on his Liberty Bell 7 capsule came off, and the craft began to fill with water. Marine divers rescued Grissom, but not the sodden capsule, which was finally dredged up four years ago. NASA

GEMINI VIII astronauts David Scott, above, and Neil Armstrong somehow kept level heads when their craft began to spin out of control after docking with another vehicle. They undocked, but the ship spun faster. Ten dizzy minutes later, balance was restored by firing the thrusters. NASA

crews head for the launch pad. Astronauts have to be either stupid or brave to step aboard their craft — and none are stupid.

Columbia's death is an appropriate time to remember other space missions that went very wrong. Many of those were tragic, and some kindle disbelief. Recounting these events does not imply that NASA or the Russians are incompetent bumblers. Far from it. Sharp minds, dedicated engineers, and courageous astronauts comprised the cast of characters — even if bureaucracy sometimes provided the epoxy that gummed up the gears of good judgment.

When you consider the enormity of the task, it's amazing that 111 shuttle flights have worked flawlessly. But it's the tragic failures we remember.

The problem was — and still is — easy to grasp: Explosives-laden, ultra-high-speed, cutting-edge machinery is blasted away from the vise-like grip of Earth's gravity. When you consider the enormity of the task, the complexity of the technical challenges, it's rather amazing that 111 shuttle flights have worked flawlessly. But it is the tragic failures that are emblazoned in our memories.

Wobbly first steps

In fact, even those events that we recall as unparalleled successes never go completely without a hitch. Behind the scenes, wrinkles arise that mar such historic programs as Apollo, which the world watched with awe and pride. Consider just the first three of its lunar missions.

The initial Moon landing was rife with small glitches that were more whimsical than perilous, starting with Neil Armstrong muffing his famous speech by omitting one of its 12 words. (He should have said, "That's one small step for *a* man, one giant leap for mankind.") The second man to step down, Buzz Aldrin, felt the urine bag inside his boot break the moment he made contact with the powdery surface. He didn't choose to say anything into the live mike, but his walks could have been characterized as "one small squish for man." The final indignity occurred when the American flag, which had been planted on a mast with much difficulty and fanfare, fell over as if on cue at the moment of lunar blast-off.

Apollo 12, launched only four months after that first adventure, began with an adrenaline rush. Thirty seconds after blast-off, their Saturn 5 rocket was struck by lightning. All the breakers tripped, the astronauts' hearts pounded — and then, luckily, the mission continued.

An incredibly accurate landing made up for the wild start. They touched down just 200 yards from the old robotic Surveyor 3 spacecraft, as planned, and hopped over to remove chunks of it to study the effects of materials exposed on the Moon for 30 months. When analyzed later — a shock: A living bacterium was found. A germ, a streptococcus, had not only contaminated a piece of the spacecraft but had survived for 2.5 years through the Moon's baking heat, –200° F cold, and total vacuum. (No wonder it's so hard to shake a strep throat.) The goof: The original equipment brought to the Moon wasn't sterile.

That mission's series of strange events continued right to its final moments. On splashdown in the Pacific Ocean, a heavy camera supposedly attached securely to a wall shook loose and smashed into Alan Bean's head. Blood gushed and the victim

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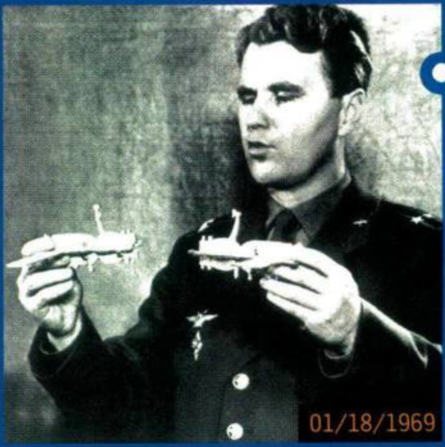
Bob Berman *is adjunct professor of astronomy at Marymount Manhattan College and the author of three books. His latest is* Strange Universe, *which will be published by Henry Holt this fall.*

01/27/1967

APOLLO 1 astronauts Gus Grissom, Ed White, and Roger Chaffee died when an electrical short sparked a fire in the command module's pure oxygen environment. On each future mission, NASA installed a better escape hatch and a system to dilute the oxygen for ground tests. NASA

04/24/1967

VLADIMIR KOMAROV, left, became the first man to die in spaceflight when his problem-plagued Soyuz 1 craft crashed on return to Earth. Forced to manually fire the motor to stop orbiting, he died when the craft's primary parachute failed and the backup became tangled. PETER GORIN/NASA



01/18/1969

SOYUZ 5 had undocked from Soyuz 4 (illustrated above by Soyuz 4 commander Vladimir Shatalov) when it re-entered Earth's atmosphere backward. Miraculously, it righted itself and cosmonaut Boris Volynov survived a crash landing 1,200 miles from his target. PETER GORIN/NASA

lay unmoving, his wide-open eyes staring blindly. Said fellow astronaut Pete Conrad, "It knocked him cold. I thought he was dead."

Because the crew knew they were going to be on global TV in a matter of minutes, a giant Band-Aid was used to conceal the injury, which remained the worst suffered by an astronaut in any of the actual Apollo flights.

Four months later, in 1970, the next trip to the Moon eventually earned its own Hollywood movie, Apollo 13. An oxygen tank exploded and blew out an entire side of the service module on April 13th. The only other oxygen tank began to leak, starving the remaining fuel cell, and the crew gave up on a Moon landing. Astronauts Jim Lovell, Jack Swigert, and Fred Haise moved into the lunar module for 86 hours, straining its intended capacity of two people for 48 hours. Staring out the window, trapped helplessly between the Scylla of space and the Charybdis of their dwindling oxygen, the crew barely survived. Four days of shivering in dark, 38° F dampness was compounded for astronaut Haise by raging fevers and a kidney infection; Lovell lost 14 pounds. Venting waste overboard was impossible, so urine had to be stored in imaginative places, such as unused Moon-rock bags. By insisting on proceeding with a mission labeled "13" to demonstrate its disdain for superstition, NASA ended up adding to the number of people suffering from triskaidekaphobia.

/// HOW MUCH RISK IS TOO MUCH?

WHEN THINGS GO WRONG, engineers and analysts face the daunting task of preventing future accidents. After Challenger's notoriously flawed O-rings failed, the booster rockets were made safer to make liftoff more secure. But tragedy struck Columbia during re-entry. It's always something. While problems sometimes take experts by surprise, they're usually known elements of risk that simply cannot be made 100-percent foolproof.

Can space travel be made less hazardous? Of course. The question, to be blunt, is how much is it worth to improve safety by a factor of two, three, or 10? When we drive, each 30-mile round-trip to the mall carries a death risk of one chance in 2 million. If those odds could be cut in half (for example, with built-in breathalyzers so the car wouldn't operate if the driver was inebriated), but each car were $1,000 more expensive, should the change be mandated? Similarly, should NASA spend a billion dollars more per shuttle flight — possibly pricing themselves out of the space game — to reduce the chance of disaster, say, threefold? Such questions of morality and practicality are debated periodically in the space agency.

While the human losses are tragic, NASA engineers know that perfect safety is impossible. If the public can't live with any risk, manned missions should be scrapped, which is what many scientists have said all along. Send unmanned probes, robots. Safer and cheaper.

But that, most agree, is not really an option. Maybe it's because we've come this far — the International Space Station is only partially built. We're like Sisyphus, compelled to roll a boulder uphill even though it rolls right back down; we just can't quit. Or perhaps it's the romance that belongs to manned flight alone. Who would want to pull the plug on those dots of light gliding noiselessly over our homes as they carry a few lucky souls suspended above Earth? — *B. B.*

Bugs in the code

Some errors are just plain ridiculous. For example, many historical mistakes can be blamed on a lack of punctuality. But punctuation? It happened. In 1962, the Venus-bound spacecraft Mariner 1 had to be destroyed because it strayed off course — a mistake caused by the omission of a hyphen in the craft's computer programming. This single punctuation mark cost taxpayers $18 million.

Another faulty instruction ordered the maneuvering thrusters of the 1988 Russian Phobos 1 spacecraft to Mars to shut down. Phobos 2, launched five days later on July 12, managed to arrive in martian orbit the following January — only to have its first computer die. The second functioned sporadically, but its commands went unheeded by the spacecraft, which went missing in March. These losses didn't surprise many people.

APOLLO 12 was struck by lightning after launch but landed safely on the Moon, where crew members took away pieces of the Surveyor 3 probe (above with Charles Conrad) that had landed two years before. A germ on the parts turned out to be Earth-born. NASA

APOLLO 13 suffered an oxygen tank explosion on April 13 that nearly cost astronauts Jim Lovell, Jack Swigert, and Fred Haise their lives. Giving up on a Moon landing, the crew crowded into the lunar module, where they cobbled together a CO_2 filter (above, with Swigert) to stay alive. NASA

SOYUZ 11 cosmonauts Georgi Dobrovolsky, Vladimir Volkov, and Viktor Patsayev could not be revived when a blown valve leaked the air from their descent module. Soyuz crew sizes were then lowered from three to two to accommodate bulky but lifesaving pressurized suits. VIDEOCOSMOS

The Russians have an unblemished failure record of attempts toward the Red Planet. Sixteen tries, zero complete successes.

A decade later, in 1999, U.S. programmers (as if in a game of one-upmanship) managed to outdo the Russians when the Mars Climate Orbiter spacecraft plunged to its doom in the thin martian atmosphere. Two teams of scientists had each programmed the craft using conflicting units, one English, one metric.

> Astronauts have to be either stupid or brave to step aboard their spacecraft — and none are stupid.

And space science goof-ups are almost always hugely expensive. The archetypical U.S. foul-up was the Hubble Space Telescope fiasco in 1990. Its 94.5-inch mirror was the most precisely polished ever made — except that it was cut to the wrong shape. Turns out that during a test of the optical surface, Perkin-Elmer technicians used an expensive, state-of-the-art device called a reflective null corrector that reported the mirror was perfect. But when they double-checked the shape with an older, less sophisticated instrument called a refractive null corrector, it revealed a serious error. (In this case, serious meant the outer edges were too low by 1/50 the thickness of a hair.) Perkin-Elmer decided the older instrument must be wrong. It cost three years, an intricate, risky repair mission, and at least $20 million to correct the telescope's spherical aberration.

The ultimate sacrifice

But no matter how expensive the mistake, the real costs come when human lives are lost. No one who heard them can forget the screams of the three Apollo 1 astronauts when a simple spark, a minor short, turned their pure-oxygen environment into a blinding inferno that melted their spacesuits around their bodies during a 1967 practice on the launch pad. (The more palatable official account says the three perished inhaling carbon monoxide. Unfortunately, not true.) Actually, the craft's oxygen environment wouldn't have been so bad in space where a fire's combustion products tend to surround and smother the flame. But in Earth's gravity (where heat and smoke rise and new air is pulled in to feed the fire), a launch-pad practice in a pure oxygen environment was an awful idea.

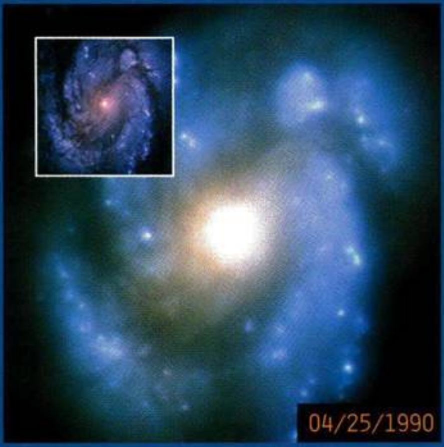
To this day, people still speculate about the four-minute-long anguish of the 1986 Challenger astronauts, that handsome, winsome crew, as they fell, alive and fully conscious, until their still-intact cabin smashed into the sea at 207 miles per hour. *The New York Times* later took NASA to court to force them to release the final recordings within the doomed, plummeting capsule. NASA regarded the intercom conversations as private while the media perceived them as legitimately public, like jetliner cockpit voice recordings. After a volley of appeals, the courts ruled against the *Times*, so we will not know what those astronauts' final minutes were like for many years to come.

Oddly, all 17 space-bound astronauts on American missions who suffered fatal accidents did so during a single black-lined week between January 27 and February 1, albeit of different years. The Russians have fared even worse. And they have their own unlucky time of year.

Despite the fact that previous unmanned flights of the Soyuz design had all failed, cosmonaut Vladimir Komarov was sent up in Soyuz 1, which crashed into Earth at about 300 miles per hour after its parachutes failed to open properly. Reportedly, he wept while speaking

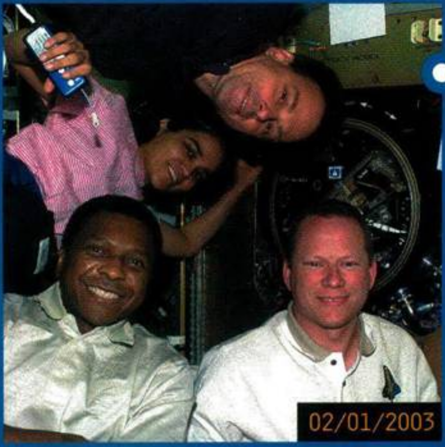
01/28/1986

THE SPACE SHUTTLE CHALLENGER exploded just after launch, killing six astronauts and teacher Christa McAuliffe when their cabin plunged into the Atlantic. Cold weather stiffened plastic washers between booster rocket joints, allowing hot gases to escape and ignite. NASA



04/25/1990

THE HUBBLE SPACE TELESCOPE suffered from blurry vision due to a misshape in its primary mirror. A month before the first servicing mission sharpened its gaze, its view of galaxy M100 in Coma Berenices was hazy (center). The inset shows how much its sight improved. NASA AND STSCI



02/01/2003

THE SPACE SHUTTLE COLUMBIA was just 16 minutes from landing when it broke apart after nearly 15 days in space, killing all seven of its crew members. The international team enjoyed exceptional camaraderie, as evidenced by photographs such as this one, taken January 27. NASA

to his wife from orbit, knowing the probable outcome that lay minutes away.

Boris Volynov, the first Jewish cosmonaut, had nothing but trouble yet managed — barely — to survive. His 1969 Soyuz 5 mission suffered multiple problems, and things turned critical during reentry when his Equipment Module failed to fully detach. Blocking the heat shield, it caused the capsule to lose stability, and he entered Earth's atmosphere tumbling out of control. When the module finally ripped off and the craft stabilized, the wrong section (its thin-skinned nose) was facing forward and the hapless craft started burning up. Smoke filled the cabin, which was actually beginning to break apart, when the craft miraculously flipped over, heat shield now properly forward.

But still his troubles weren't over: When the parachutes emerged, they only partially deployed. Volynov could do nothing but wait to die (like luckless Komarov) in the high-speed landing. But when the dust cleared from the brutal impact he was still alive, although some of his teeth had been knocked out. When rescuers finally arrived (mission controllers had lost track of him), Volynov had already walked to the nearest town, a toothless intruder attempting to convince villagers he'd just come from space.

The deadliest disaster in the history of space programs was overseen by Mitrofan Nedelin, commander of Russia's rocket program. On October 24, 1960, at the famous Baikonur launch site (named for a distant town to confuse Western intelligence), Nedelin sat on a folding chair next to the giant rocket about to be test-fired. Over workers' objections, he insisted on saving time by having a faulty electric circuit fixed on the spot, without draining the fuel tanks that had just been filled. Still firmly mated to the huge propellant-laden main stage, the upper stage suddenly fired. The resulting fireball killed at least 92 people and injured another 30, more casualties than in all other space mishaps combined.

Three years later to the day, an oxygen leak caused another explosion that killed eight at the same site. From then on, workers have refused to perform their duties at Baikonur on October 24.

For some astronauts, bad mishaps could have been even worse. One Mercury astronaut, Gus Grissom, nearly drowned after exiting his just-landed capsule, which sank when the hatch mysteriously blew. And Neil Armstrong only lived to go to the Moon because he survived a practice mishap a few months earlier — he ejected just before his lunar landing research vehicle crashed. The margin between life and death had been two seconds.

Choosing a destination

Just as good and bad fortune seem attached to particular dates, Lady Luck has smiled on some destinations and frowned on others. The Moon has generally been a good-luck place, as have the giant planets. NASA sent five intricate, high-tech spacecraft to Jupiter, and four to Saturn; so far all have worked beautifully. We're one-for-one to Mercury and have a generally good record to Venus.

But for reasons only paranoid theorists can explain, Mars has been a problem. Despite being closer than the gas giants, the Mars success rate has resembled that of dot-com companies. Of the 30 U.S. and Russian spacecraft launched to the Red Planet, 21 have exploded, crashed, or malfunctioned. Conspiracy-lovers have pounced on that slim 9 for 30 success rate, contending that malevolent Martians do not like our snooping. (Apparently the aliens were napping during the arrival of the twin Vikings of 1976, the Pathfinder and Global Surveyor missions of the 1990s, and the recent 2001 Mars Odyssey. All worked flawlessly.)

Leaps of faith

Yet if we send humans to any new destination, it will be to the bad-luck planet. Of course, none of us is superstitious, and all that silly number 13 business is long in the past. So you'd have no problem volunteering, right? Right? That all too human hesitation is further reason to salute the valor of the pioneers who have paved the way. ■

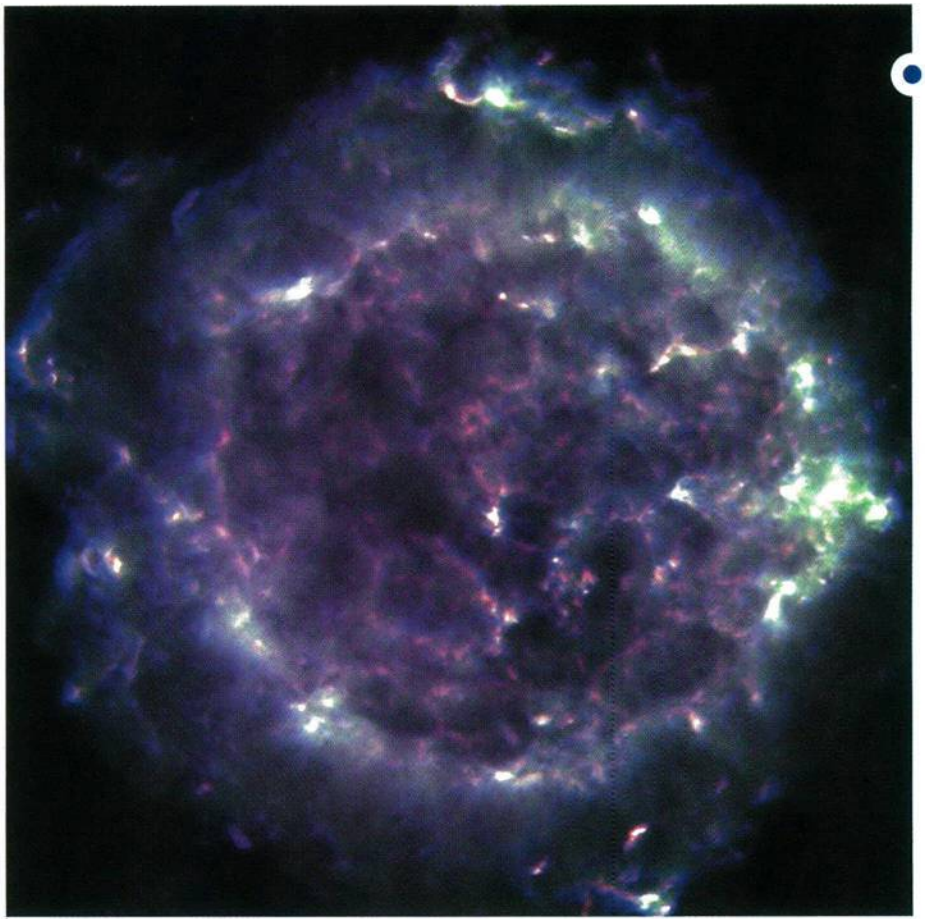
To learn more about space disasters, go to http://www.astronomy.com/toc

Seeing sharper

Using a technique long practiced by radio astronomers, optical astronomers hope to see finer detail than ever before. /// BY ROLF DANNER AND RAY JAYAWARDHANA

While science fiction writers have long asserted the existence of other inhabited worlds, scientists have only recently begun to gather the first definitive evidence for planets circling nearby stars. Over the past eight years, astronomers have discovered more than one hundred planets by detecting the wobble of their parent stars induced by the planets' gravitational pull, and in a few cases by seeing the tiny dip in a star's light as a planet crosses its face. All the planets discovered so far are quite massive, most likely gas giants like Jupiter and Saturn. But if we ever want to find the surface temperature of an Earth-sized extrasolar planet, whether it has an atmosphere and what it consists of, and whether there is biological activity, we will have to analyze light from the planet directly — a formidable challenge.

Astronomers are now getting ready to take up that challenge. Someday, in the not-too-distant future, it may be possible to take a picture of an extrasolar planet, thanks to an amazing technique now being developed for use on the world's largest optical telescopes. Interferometry, as it is known, allows astronomers to combine, or "interfere," light waves collected by two or more telescopes to achieve far greater resolution than ever before. Pictures taken by interferometers allow us to see fine details that single telescopes cannot and offer the prospect of separating a planet's light from that of the bright parent star next to it.



SUPERNOVA REMNANT CASSIOPEIA A shows incredible detail in this image taken with the Very Large Array radio interferometer. For decades, radio astronomers have been using interferometry to create images, a technique that optical astronomers hope to master soon. NRAO/AUI

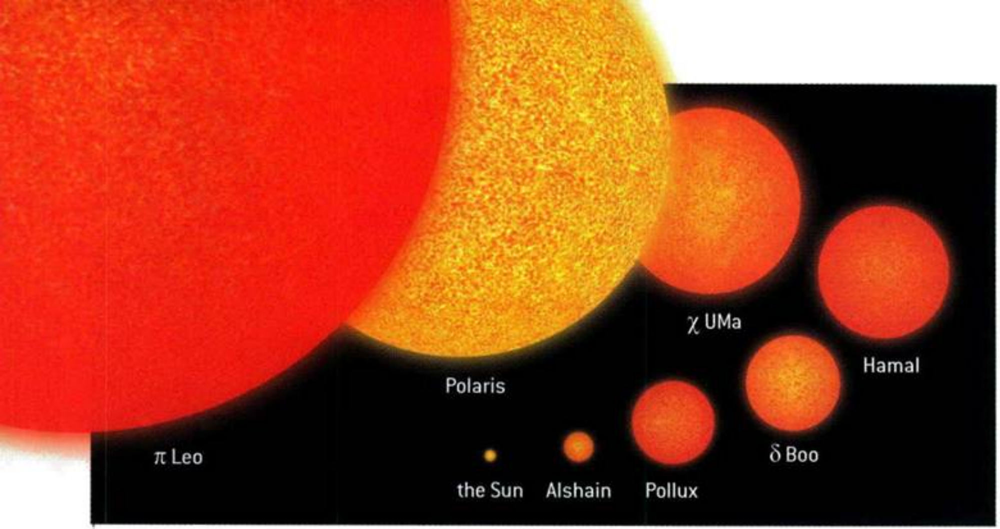
The birth of interferometry

Even though optical interferometry is only now coming of age, its origins date back nearly a century. Toward the end of the 1800s, Albert Michelson developed techniques for ultra-precise measurements of light. His groundbreaking studies of the speed of light laid the observational foundation for Einstein's theory of special relativity. And in 1907 he became the first American to win a Nobel Prize in physics.

When Michelson turned his attention to astronomy in the 1920s, researchers had measured the size of only one star: the Sun. No existing telescope had sufficient resolution to see even the largest stars as anything more than dots blurred by Earth's atmosphere. Michelson had access to the largest telescope in the world — the 100-inch Hooker Telescope on Mount Wilson — but he knew from theoretical estimates that he would need about twice its resolution to measure the sizes of distant stars. So he set out to improve the giant telescope.

The resolution of a telescope is its ability to distinguish two stars that appear very close to each other. For telescopes, the maximum resolution is limited only by the diameter of the

THE VERY LARGE TELESCOPE INTERFEROMETER (VLTI) will connect the four 8.2-meter Unit Telescopes (far left) to make an instrument having the resolution of a telescope with a mirror 200 meters across. The VLTI rests on 8,700-foot-high Cerro Paranal in Chile, in the Atacama Desert less than 10 miles from the Pacific Ocean. Light from the telescopes gets directed underground into the Interferometric Tunnel (left), where the beams of light are combined. This view shows the rails for two delay lines, devices that compensate for the differences in the path lengths of the light beams from the various telescopes. ESO



PRECISELY MEASURING STAR SIZES is one task ideally suited to interferometers. So far the Navy Prototype Optical Interferometer has gauged seven stars, each with a diameter much larger than the Sun. *ASTRONOMY*: ROEN KELLY **THE NAVY PROTOTYPE OPTICAL INTERFEROMETER** (right) on Anderson Mesa in Arizona has six elements. It is a joint project of the U.S. Naval Observatory, the Naval Research Lab, and Lowell Observatory. USNO/NRL/LOWELL OBSERVATORY

primary lens or mirror. If we double the diameter, we double the resolution.

In Michelson's time, the 100-inch telescope was the largest that could be built. He couldn't just ask for a bigger one. He also knew that he didn't need to. From his studies of light, he understood that only the outermost parts of the mirror contributed to a telescope's resolution. All of the mirror's surface inside this outer ring does not improve resolution; it only adds to the light-gathering power.

Michelson decided to "enlarge" the 100-inch telescope by adding an extension bar across its front end. This structure supported two small, adjustable mirrors separated by about 5 meters (200 inches), or twice the diameter of the Hooker Telescope. These mirrors alone collected the starlight, then directed it to two additional mirrors closer in that reflected it into the telescope's tube. The largest telescope in the world just held the structure in place and combined the light from the two outer mirrors.

By moving the two mirrors closer together and farther apart, Michelson was able to adjust the resolution of the arrangement until it equaled the angular diameter of Betelgeuse, a bright red star in Orion. This was the first time anyone had been able to directly measure the diameter of a star other than the Sun.

Interferometry has come a long way since Michelson's early experiments, especially in radio astronomy. Because the wavelengths of radio waves are typically 10,000 times longer than those of visible light, it's a lot easier to work with them. The Very Large Array (VLA) consists of 27 individual antennae laid out in a "Y" pattern in the New Mexico desert. For more than twenty years, the VLA has allowed radio astronomers to see details in objects that optical astronomers can only dream about. In recent years, astronomers have combined ten radio antennae spread from Hawaii to the Virgin Islands. This Very Large Baseline Array can resolve detail as fine as one giant radio telescope with a 5,000-mile-wide antenna.

Light and interference

All forms of light, from gamma rays through visible to radio, can be thought of as electromagnetic waves. Waves can be observed in many places — a coffee cup, a quiet pool, at the beach. Scientists and engineers use two quantities to describe any wave: wavelength and amplitude. Wavelength measures the separation between two consecutive crests or troughs of a wave. Amplitude is one-half the height between the lowest point in a wave's trough and the top of the next crest.

We see our surroundings in different colors because our eyes detect light of different wavelengths. Red light has a longer wavelength than blue light. Conversely, we notice objects of different brightness because we receive light waves with different amplitudes. A bright source radiates light with a larger amplitude than a dim source.

> { **The bright colors of hummingbirds and butterflies** are created by the interference of white light.

Two waves that match perfectly in wavelength and amplitude can sometimes interact. If the two waves overlap so that the crests of one wave coincide with the crests of the other, the waves will amplify each other and the result will be a wave with twice the amplitude of the two single waves. But a subtle change will produce a dramatically different result: Shift one wave by half a wavelength with respect to the other, so that the crests of the first coincide with the troughs of the second, and the waves cancel each other. Light plus light adds up to darkness.

Because the wavelength of visible light is much shorter than the dimensions of most everyday objects — about 1,000 wavelengths fit across a dust speck — we

Rolf Danner *is a research scientist at NASA's Jet Propulsion Laboratory. Contributing editor* **Ray Jayawardhana** *is an assistant professor of astronomy at the University of Michigan.*

rarely notice these subtle effects. When you see an array of shimmering rainbow colors on a puddle in the street, you're seeing the result of interference, the cancellation of light waves on a thin film of oil on the water's surface. The bright colors of hummingbirds and butterflies are also created by the interference of white light, which is a mixture of all wavelengths. Because the conditions are just right to amplify one particular color, only that color is brilliantly reflected.

Interferometry 101

A basic interferometer consists of two telescopes collecting light. Mirrors send the light from each of the telescopes to a device called a "beam combiner," which overlays the two beams of light. A beam combiner can be as simple as a semitransparent mirror set at a 45° angle to the incoming beam. From the beam combiner, the light from the two telescopes travels to a detector.

Now imagine pointing this interferometer at a star that emits light of only one wavelength. If the light path through the first telescope to the detector differs by exactly one or several wavelengths from the path through the second telescope, the two waves amplify each other and the detector will see a bright output. If the two paths differ by exactly half a wavelength of the incoming light, the two beams will cancel each other.

Because the result depends so sensitively on the paths the light travels from the telescopes to the detector, astronomers often insert an additional component in one of the paths, or "arms," of the interferometer. Called a delay line, this device consists of a set of moveable mirrors. If the mirrors are moved farther apart, light through one arm will travel a greater distance. In the example of the one-color star, the signal at the detector would go from zero to maximum if the delay line changes the path by half a wavelength. So far this is interesting, but not terribly useful.

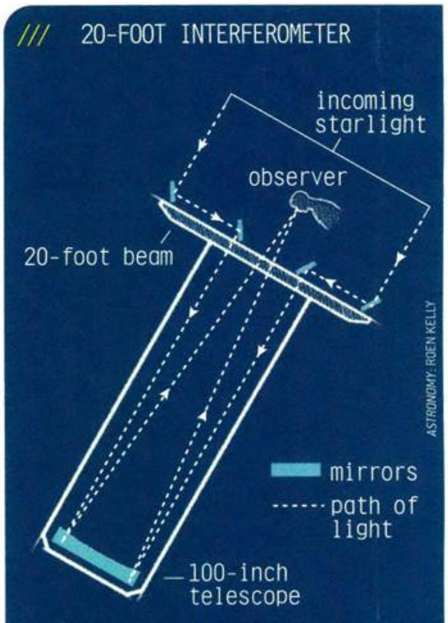
In reality, stars don't shine in a single color but send out light over a wide range of wavelengths. And for each wavelength, the delay line would need to be set differently to either cancel the two beams or let them amplify each other. For white light, only one setting of the delay line provides the correct interference for all incoming wavelengths: The path length from the star through the first telescope to the detector must exactly match the path length from the star to the detector through the second telescope. The detector won't record a full cancellation or a doubling of intensity at any other position of the delay line.

The correct position depends only on the orientation of the interferometer relative to the incoming starlight. If one arm of the interferometer points toward the star, then the path through this arm needs to be delayed to accurately match the path through the other arm.

The precision to which this alignment can be measured depends on the separation of the collecting telescopes, usually called the baseline. Think of the base as a stiff rod, commonly tens of meters long, laid down on a perfectly smooth floor. Now lift one end of the rod by fractions of a wavelength of visible light. In our case, this means lifting one end by an amount 10 million times smaller than the length of the rod. This is the precision to which you can measure the angle between the rod and the floor, and the accuracy to which you can measure the relative orientation of the interferometer arms to the incoming starlight.

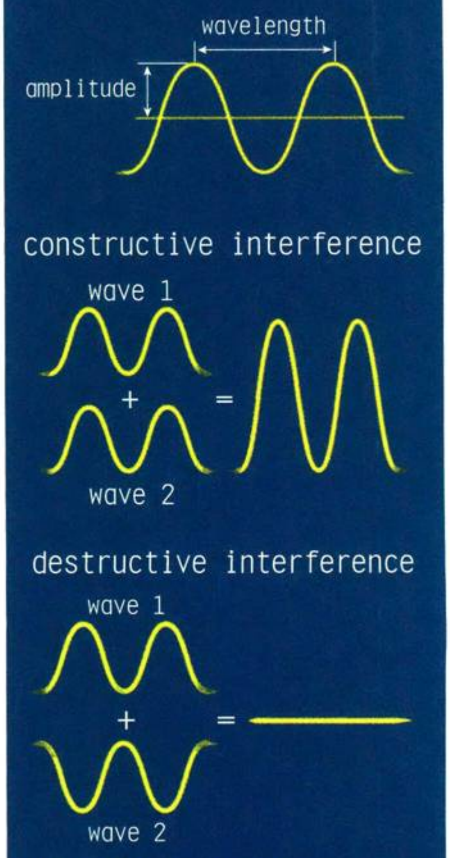
This analogy makes it easy to explain two other aspects of interferometers. If you double the length of the rod on the floor (doubling the baseline) but lift one end of the rod by the same amount, the rod and floor will subtend only half the previous angle. So if you double the separation between the two telescopes, the resolution of the interferometer also doubles.

On the other hand, if you could decrease the distance by which you lift one end of the rod, then the rod and



ASTRONOMY: ROEN KELLY

MICHELSON'S INTERFEROMETER used two small mirrors attached to a 20-foot-long beam on the front of the 100-inch Hooker Telescope to resolve the star Betelgeuse.



WAVELENGTH AND AMPLITUDE fix a light source's color and brightness. If two identical waves overlap exactly, they interfere constructively, yielding a wave with twice the amplitude. Shift one wave by half a wavelength and the two cancel each other.

THE PALOMAR TESTBED INTERFEROMETER (left) in Southern California consists of three 20-inch telescopes working together. The device is testing techniques that will be used on the Keck Interferometer. NASA/JPL/CALTECH **THE STAR ALTAIR** (right) in Aquila shows a slight equatorial bulge in this image from the Palomar Testbed Interferometer. The bulge results from the young star's rapid rotation. NASA/JPL/CALTECH/STEVE GOLDEN

floor will again subtend a smaller angle. The unit by which you can adjust this arm is the wavelength of the star's light you are observing. So if you observe at half the wavelength while keeping the baseline constant, the precision of your measurement again doubles.

In real observatories, the telescopes and all elements of the interferometer are connected firmly to bedrock. Therefore, astronomers can determine the position of a star relative to the interferometer, and in turn the observatory location, by measuring the position of the delay line where light from the two telescopes combines to a maximum. The tremendous precision of an interferometer stems from the huge ratio of the baseline length to the wavelength of visible light.

The Terrestrial Planet Finder spacecraft may even be able to deduce signs of biological activity on the surface of a distant planet.

Making images

As complicated as this sounds, it doesn't shed any light on how interferometers can be used to take images. Imagine your dog taking several big bites out of your favorite, formerly round bathroom rug. Now you want to accurately describe the shape of the mangled rug. One way would be to take a measuring tape and stretch it across the rug, making sure the tape goes over the purple rose in the old center of the rug. Now write down the length of the rug in this direction.

Next, turn the tape so that you measure the rug at a slightly different angle, making sure the tape still runs over the purple rose. Continue turning the tape, measuring the rug's dimensions, and writing down the results until you have turned the tape at regular intervals over half a turn. (No need to make a full turn because you always measure across the whole rug.)

Now go to a drawing table and copy the dimensions onto graph paper at whatever scale you like. First draw a line and record the first measurement. Then draw a second line at the same angle as you moved the tape measure and record the second measurement. When you have finished recording all the dimensions, you will see a scaled outline of your rug on the graph paper.

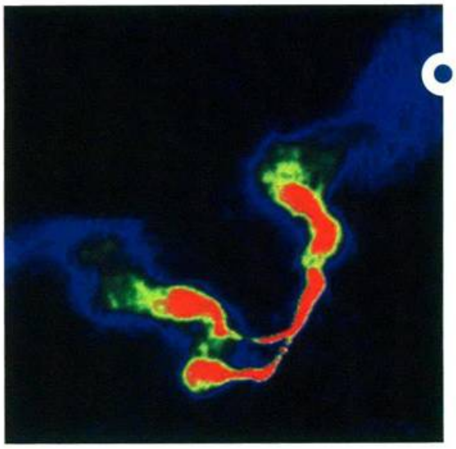
If you want to take an image of an irregular object, something has to take the role of the measuring tape. Michelson actually had it relatively easy when he determined the diameter of Betelgeuse: He needed to take only one measurement because stars are round and have the same extent in all directions.

But how did he make his measurement? All stars appear as unresolved dots. So they all create similar interference patterns when observed through an interferometer, unless the interferometer's baseline is long enough to resolve the star. When a star is "resolved," it appears to the instrument as an extended disk, and light from different areas of that disk starts to overlap and washes out the interference pattern. Michelson simply had to increase the separation of his two small mirrors until he couldn't see the interference pattern from Betelgeuse anymore. When the pattern disappeared, he knew that the interferometer's resolution — that is, the ratio of the wavelength of the starlight to the current separation of his mirrors — was equal to the angular diameter of Betelgeuse. If you know the distance to Betelgeuse, you can figure out its physical diameter using simple geometry.

Combining a series of measurements at different baseline orientations allows astronomers to construct complex images. The more complex the object, the more measurements are needed to accurately capture its outline and shape.

Capturing a distant planet

Detecting a planet orbiting another star requires more from an interferometer than just great resolution. Not only will the planet lie very close to its parent star, but it will also appear roughly a million times fainter. Any telescope that hopes to detect the light from a planet will



THE VERY LARGE ARRAY (left) stands in the desert near Socorro, New Mexico, where its 27 antennae work together to produce exquisitely sharp images of the radio universe. NRAO/AUI **THE RADIO SOURCE 3C 75** (right) resides at the center of the Abell 400 cluster of galaxies in Cetus. The great resolution of the VLA shows the interaction between the twin radio jets associated with the galaxy's binary nucleus. NRAO/AUI, F. N. OWEN, C. P. O'DEA, M. INOUE, AND J. EILEK

somehow have to suppress all but one part in a million of the light it collects.

Interferometers accomplish this by creating an artificial blind spot. If the delay line is offset by half a wavelength for the location of the star, all its light will be canceled, or nulled. However, light coming from a slightly different direction, say from an orbiting planet, will not be canceled — letting us see the planet by removing the star's glare.

Interferometers are smart telescopes. They can be built for high resolution without the need for large or expensive mirror surfaces. In a nulling mode, they can suppress light from a small area within their field of view while remaining fully sensitive to light from the rest of the field. Astronomers will have to bring out all these capabilities and more to separate the light of a nearby star from a possible planet. Higher resolution still would be required to separate features on the surface of even the nearest extrasolar planet. This task would require mirrors separated by about 600 miles (1,000 kilometers) — a virtual telescope the size of Texas.

While this remains a challenging goal, intermediate rewards will occur along the way. Interferometers will benefit many areas of astronomy by precisely measuring the sizes and positions of celestial objects. They will test our understanding of stellar evolution by comparing measured star sizes with those predicted by theory. By tracing the positions of binary stars as they orbit each other, astronomers will be able to study their interactions. By measuring the parallax, the apparent change in a star's position resulting from Earth's motion around the Sun, astronomers can calculate the star's distance. The high angular resolution of interferometers will allow us to measure the parallax of far more distant objects, perhaps even stars in other galaxies.

These are just a few of the reasons why several major observatories are connecting multiple telescopes into interferometers. The European Southern Observatory's Very Large Telescope in Chile will eventually combine its four 8.2-meter telescopes into an interferometer. (Pairs of these telescopes have already been successfully connected.) At Palomar Observatory in Southern California, the Jet Propulsion Laboratory has built the Palomar Testbed Interferometer as a real-life test for the Keck Interferometer. This project will connect the two 10-meter Keck telescopes on Hawaii's Mauna Kea into an interferometer with the effective resolution of an 85-meter telescope. Other interferometers that have achieved preliminary results include the Navy Prototype Optical Interferometer in Arizona, the CHARA Array on Mount Wilson, and the COAST Array in England.

These ground-based efforts are already providing exciting scientific results while also contributing to the technology required to build optical interferometers in space, high above the distorting effects of Earth's atmosphere. The Space Interferometry Mission (SIM), due to be launched in 2009, will be the first long baseline (10 meter), optical Michelson Interferometer in space. SIM will be able to detect terrestrial planets indirectly through the motion they induce in their parent stars, although it will not have the resolution or sensitivity to directly detect light from extrasolar planets. However, SIM's astrometric accuracy, several hundred times better than any previous space mission, will revolutionize astronomers' ability to measure the positions and motions of distant stars. SIM will also demonstrate the technology of interferometric imaging and nulling in space for the first time.

Detecting the light from small extrasolar planets will have to wait until SIM's successor, the Terrestrial Planet Finder (TPF), is launched around 2015. One of two concepts envisions TPF as several telescopes on free-flying spacecraft separating the light of the central star from the light of the planet and analyzing this light using a spectrograph. TPF will take snapshots, or family portraits, of planetary systems around nearby stars. It will be able to determine the surface temperature of a planet, ascertain whether it has an atmosphere, and see if that atmosphere contains liquid water, ozone, and nitrogen — all the basic ingredients we believe to be essential for life. We may even be able to deduce signs of biological activity on the surface of a distant planet.

Sometime at the beginning of the next decade, we might find the answer to our question: "Are we alone?" Through the magic of interferometry, we might know whether there is indeed a place like home out there among the stars. ■

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BY MARTIN RATCLIFFE AND ALISTER LING

JULY 03

With the bright gas-giant planets sinking into the Sun's glare, Mars takes center stage — growing by a third and more than doubling in brightness.

The Red Planet's remarkable return

What's all this hullabaloo about Mars? This summer, Mars will come closer to Earth than at any time in recorded history. If you miss out on this apparition, you'll have to wait another 15 years before getting a view that comes even close. With Mars rising like a bright beacon in the late evening, you can bet UFO sightings will be on the rise. It appears as bright as a plane's landing lights but rusty-orange in color, and it will hang relatively low in the sky from the Northern Hemisphere throughout the summer. The public isn't used to seeing anything like it.

BRILLIANT MARS shines as brightly this month as it did during its stellar apparitions of the 1980s. In this shot from July 1986, it dazzles from inside the handle of the Teapot asterism of Sagittarius. CHRIS SCHUR

On July 1, the crescent Moon lies to the lower right of Jupiter as the pair sinks in the evening twilight glow. By the next night, it hangs above Jupiter. Watch the Moon glide past Jupiter in the two hours before they set. Through a telescope you can still catch Jupiter's moons slow-dancing around their king, but turbulence in our atmosphere smears the planet's fine details.

This is a good opportunity to focus on the thin crescent Moon. Despite the annoying turbulence, the array of bright crater rims and mountain peaks along the Moon's day-night terminator are a wonder to behold. Lunar observers love to watch the long, jagged shadows creeping across the floors of craters bathed in the yellow-orange light filtered by our atmosphere.

If it's clear on the morning of July 17, the close approach of the Moon to Mars will surely grab your attention. The Moon actually covers, or occults, Mars for lucky observers living in southern Florida, Newfoundland's Avalon Peninsula, and Central America. It should be a spectacular sight along the graze line, where Mars plays hide and seek with mountains and valleys on the lunar limb.

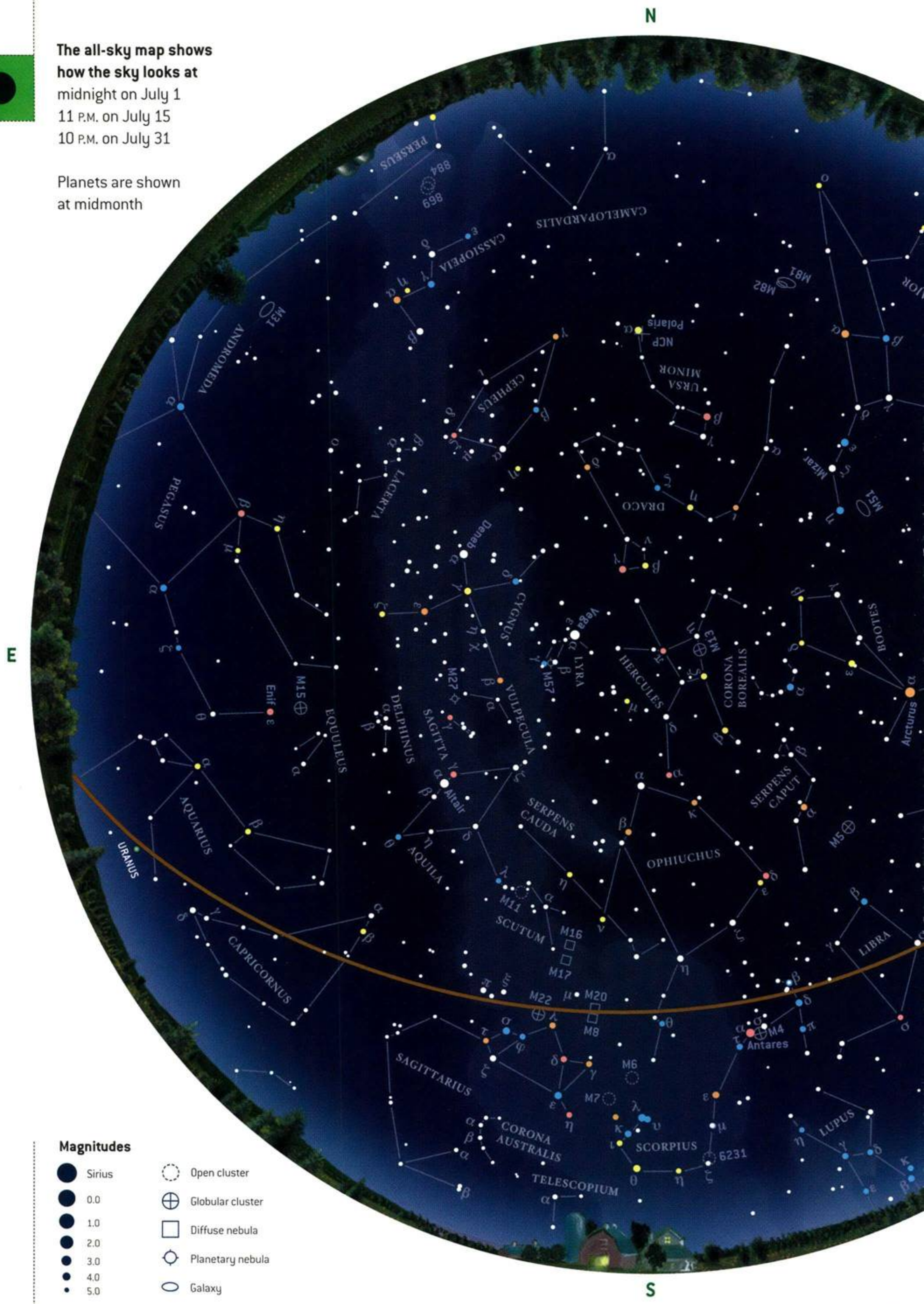
Keep your binoculars trained on Jupiter during the last ten days of July, about 30 minutes after sunset. A point of light will appear from the lower right and by the 25th will creep past Jupiter. This is Mercury, the innermost planet. A thin crescent Moon pops into view above the pair of planets on the 30th.

Every backyard observer should try to see the entire solar system family. Although our distant siblings Uranus and Neptune won't wow you like Jupiter or Saturn, they're well within reach of small telescopes and even binoculars from a city backyard. The finder charts and advice in "Gunning for the gas giants" on page 86 will help you track them down. Pluto, our fringe relative, is the toughest nut to crack. A dark sky and the charts in "Find the faintest planet" by Richard Talcott (June 2003) will help.

From the giant to the puny, the solar system has it all. Space rock 4 Vesta ranks among the largest asteroids and can be seen easily with binoculars. At the bottom of the scale, tiny grains of dust and rock flare into visibility when they burn up in Earth's atmosphere. The Southern Delta Aquarid meteor shower provides about ten "shooting stars" per hour after midnight at the end of the month. Also keep an eye out for some early Perseid meteors, which streak across the sky at far greater speeds.

The all-sky map shows how the sky looks at
midnight on July 1
11 P.M. on July 15
10 P.M. on July 31

Planets are shown at midmonth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CAPRICORNUS
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M8
M4
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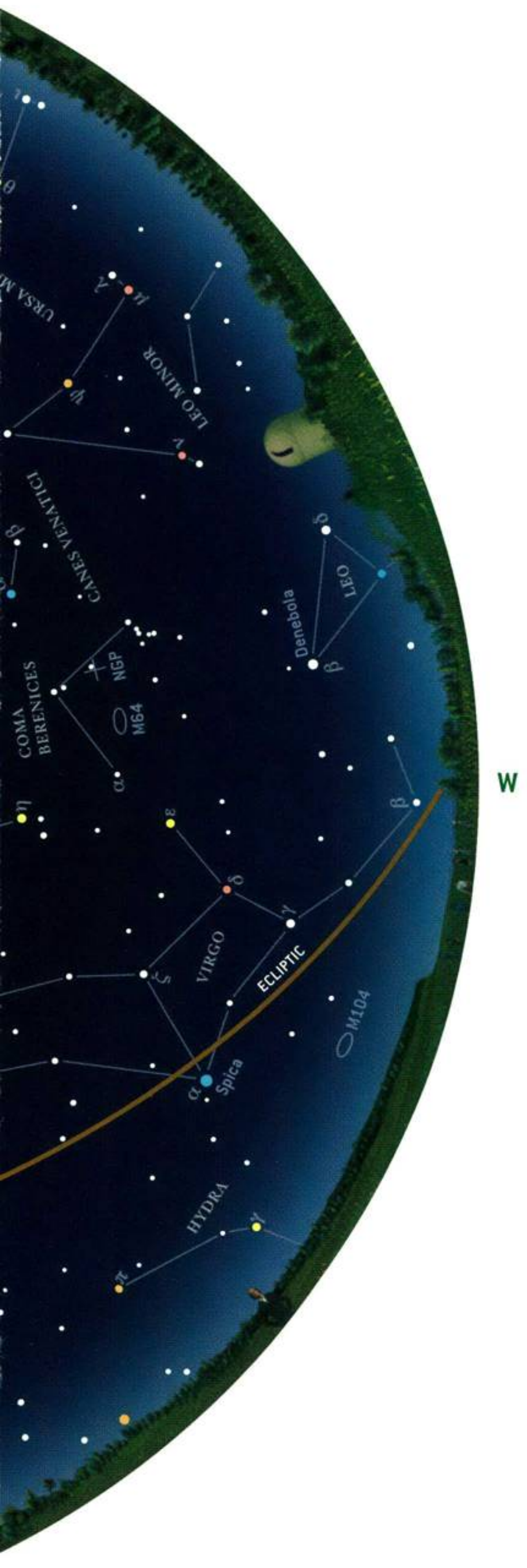
SAGITTARIUS
M6
M7
CORONA AUSTRALIS
SCORPIUS
6231
LUPUS
TELESCOPIUM

Magnitudes

● Sirius
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
• 5.0

◌ Open cluster
⊕ Globular cluster
□ Diffuse nebula
⌖ Planetary nebula
⬭ Galaxy

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions:
horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sk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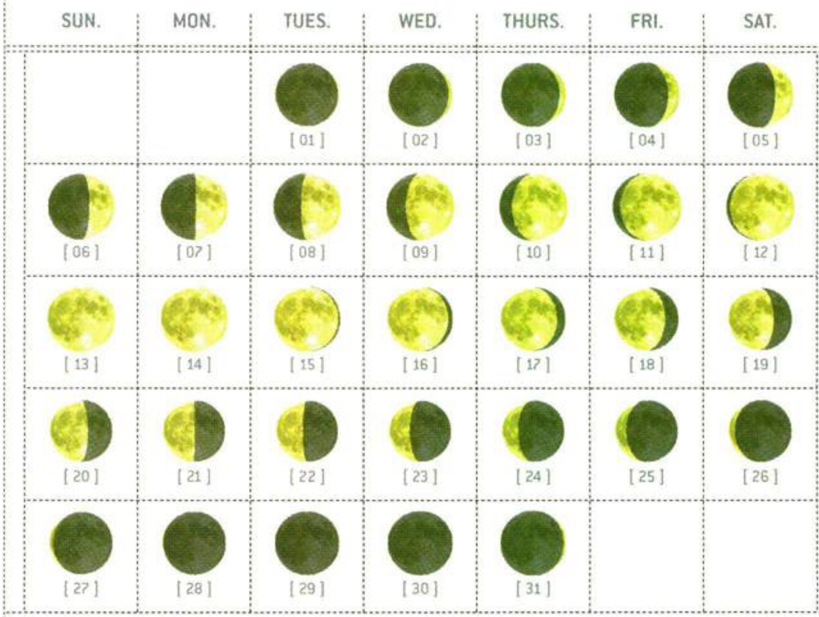
july 03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02 The Moon passes 4° north of Jupiter, 5 P.M. EDT

04 Earth is at aphelion (94.5 million miles from the Sun), 2 A.M. EDT

05 Mercury is in superior conjunction, 6 A.M. EDT

06 First Quarter Moon is at 10:32 P.M. EDT

08 Venus passes 0.8° north of Saturn, 4 A.M. EDT

10 The Moon is at perigee (226,890 miles from Earth), 6:01 P.M. EDT

13 Full Moon is at 3:21 P.M. EDT

15 The Moon passes 5° south of Neptune, 1 A.M. EDT

16 The Moon passes 5° south of Uranus, noon EDT

17 The Moon passes 0.3° north of Mars, 4 A.M. EDT

21 Last Quarter Moon is at 3:01 A.M. EDT

22 The Moon is at apogee (251,238 miles from Earth), 3:37 P.M. EDT

25 Mercury passes 0.4° north of Jupiter, 9 P.M. EDT

26 Saturn is at perihelion (839.5 million miles from the Sun), noon EDT

The Moon passes 4° north of Saturn, 8 P.M. EDT

29 Southern Delta Aquarid meteor shower peaks

New Moon is at 2:53 A.M. EDT

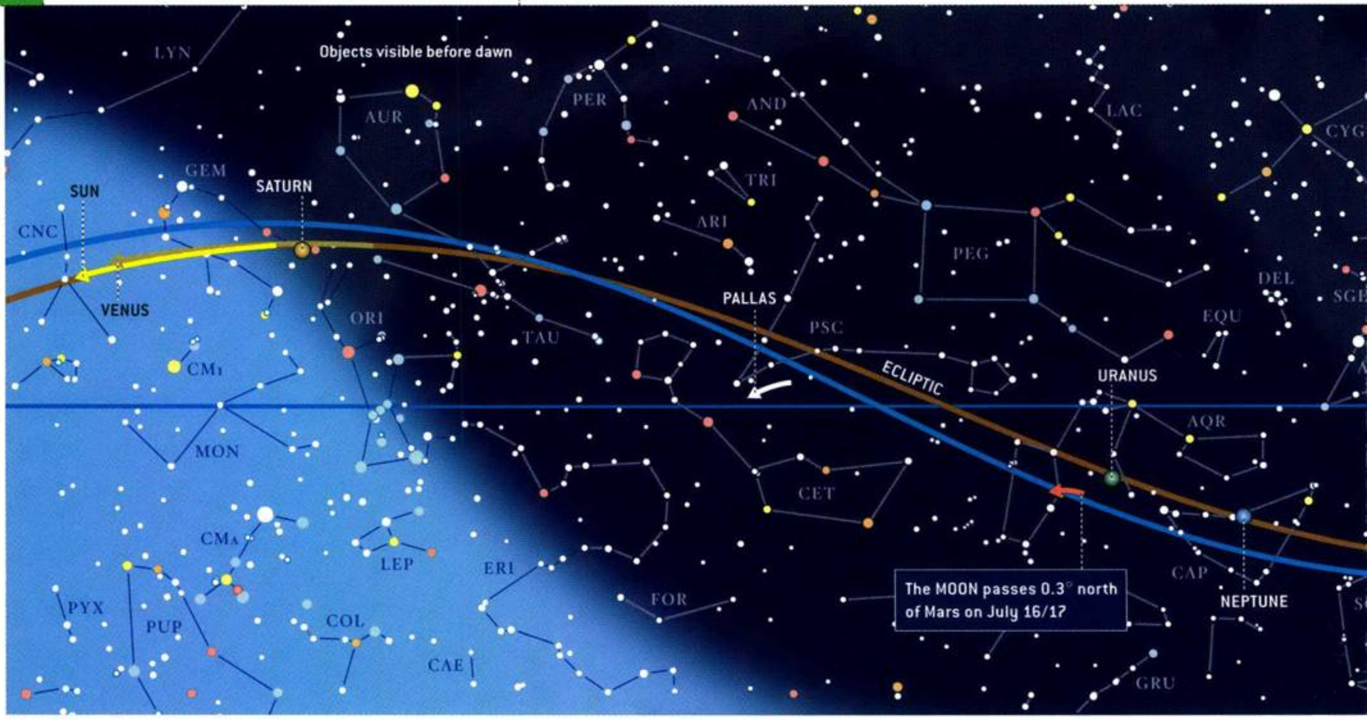
30 Mercury passes 0.2° north of Regulus, 7 A.M. EDT

The Moon passes 4° north of Jupiter, 9 A.M. EDT

The Moon passes 5° north of Mercury, 9 P.M. EDT

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and sq


Objects visible before dawn
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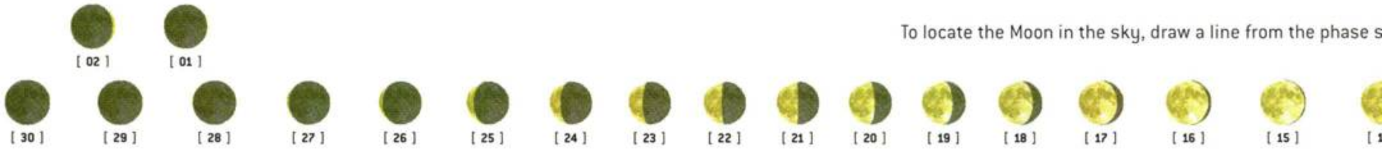
The MOON passes 0.3° north of Mars on July 16/17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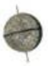
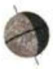
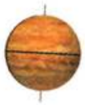
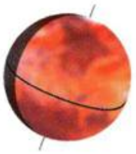
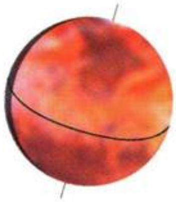
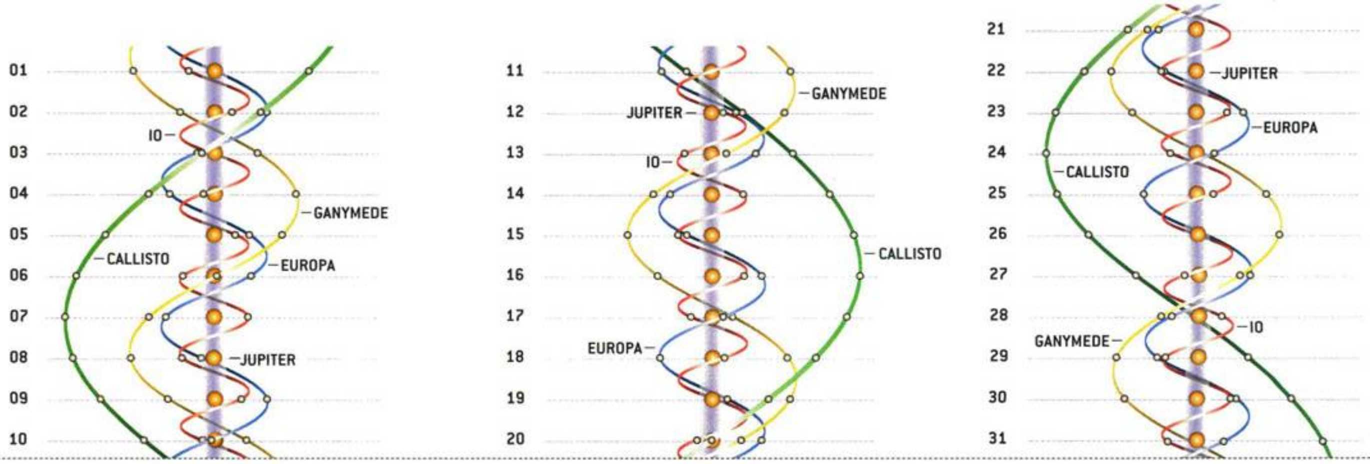
To locate the Moon in the sky, draw a line from the phase s

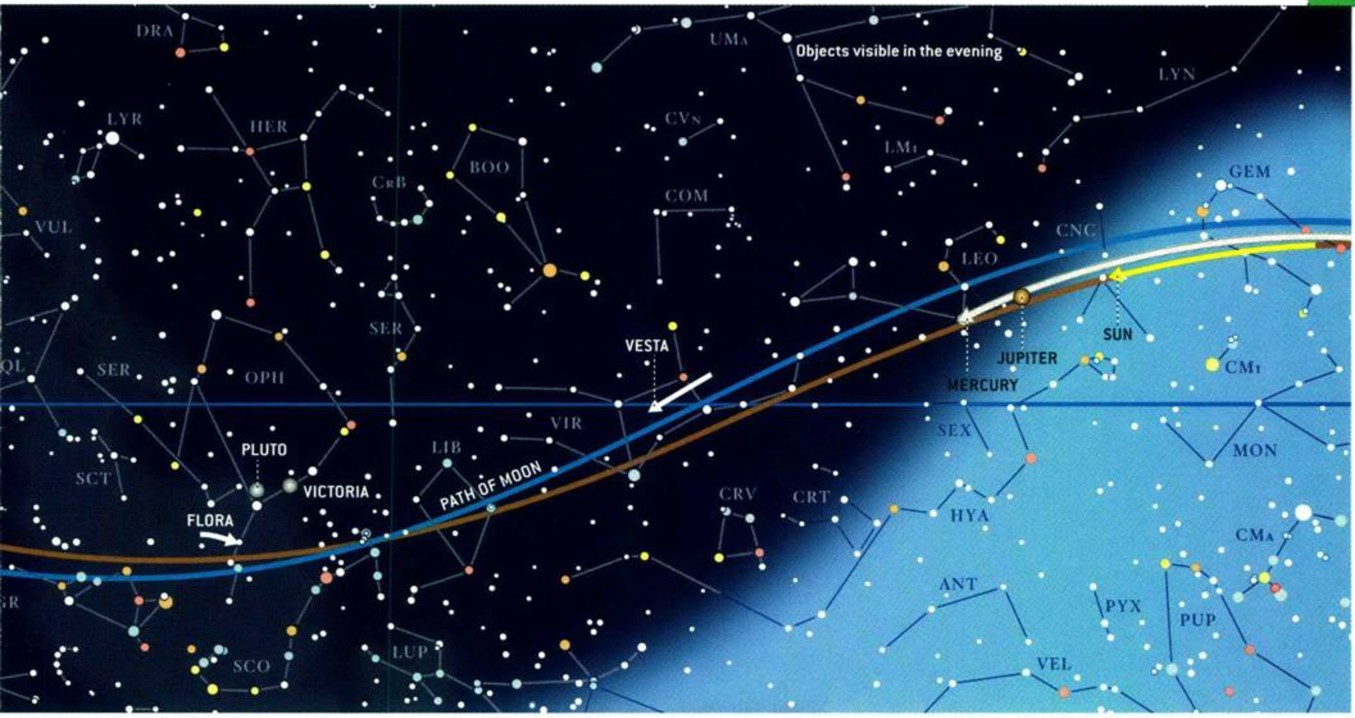
PLANETS	 MERCURY	 MERCURY	 VENUS	 MARS	 M
Date	July 15	July 31	July 1	July 1	Ju
Magnitude	–1.1	–0.1	–3.9	–1.4	–
Angular Size	5.2"	6.0"	10.0"	16.7"	2
Illumination	92%	70%	97%	90%	9
Distance (AU) from Earth	1.296	1.112	1.671	0.562	0
Distance (AU) from Sun	0.356	0.439	0.721	1.407	1
Right Ascension (2000.0)	8h22.7m	10h11.4m	5h40.0m	22h34.5m	2
Declination (2000.0)	21°17'	11°48'	23°06'	–13°37'	–

Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view in a telescope.



uares show motions and locations of solar system objects during the month.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Objects visible in the evening
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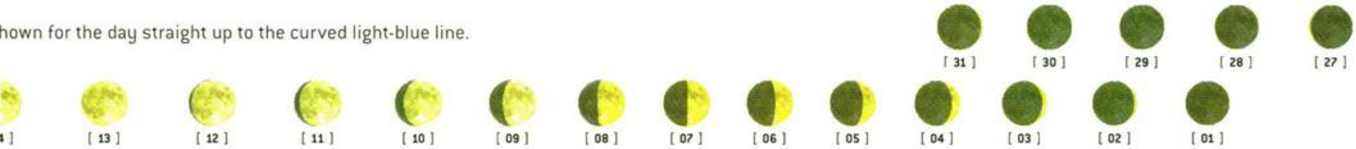
hown for the day straight up to the curved light-blue line.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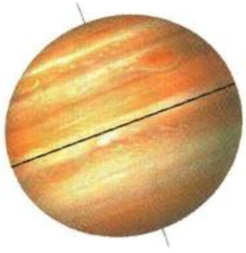
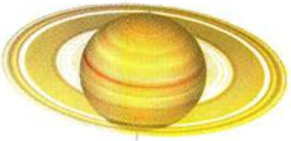
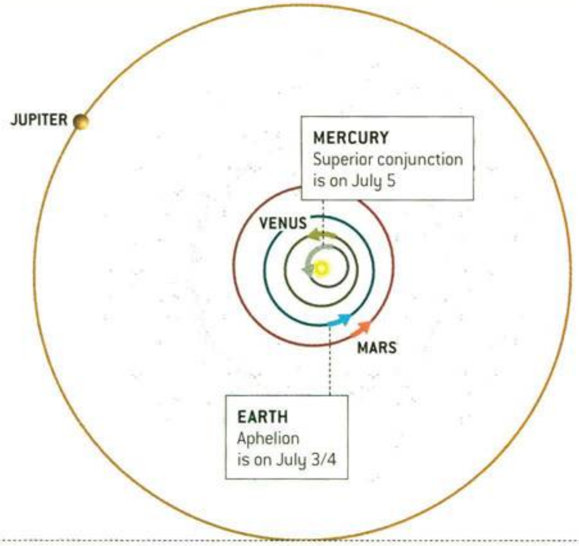




ARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
ly 31	July 15	July 15	July 15	July 15	July 15
2.3	−1.8	0.1	5.7	7.8	13.8
2.2"	31.6"	16.6"	3.7"	2.3"	0.1"
%	100%	100%	100%	100%	100%
422	6.232	9.999	19.240	29.123	29.838
388	5.362	9.031	20.028	30.079	30.671
2h55.8m	9h33.3m	6h22.7m	22h18.0m	20h59.0m	17h10.0m
13°25'	15°21'	22°34'	−11°25'	−17°07'	−13°29'

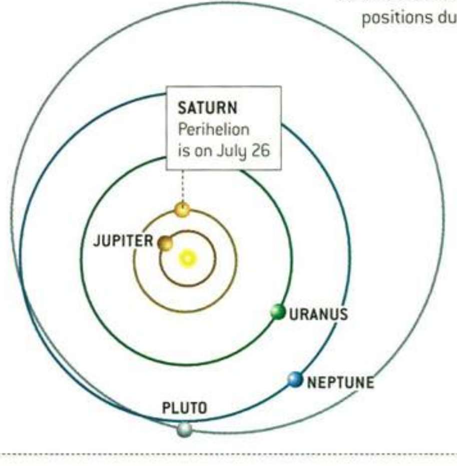

JUPITER
VENUS
MARS

MERCURY
Superior conjunction
is on July 5

EARTH
Aphelion
is on July 3/4

The planets in their orbits

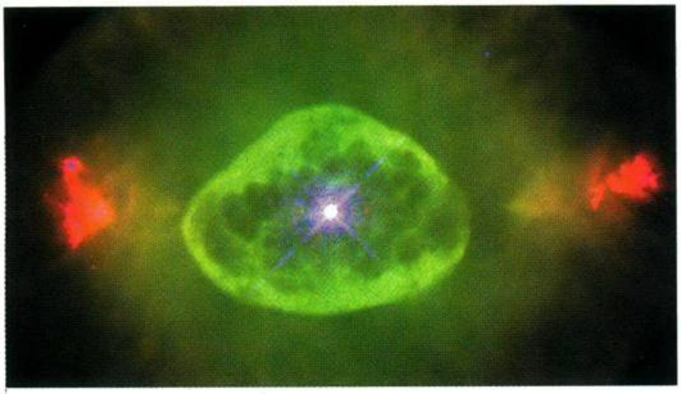
Arrows and dots show planets' positions during the month.


JUPITER
URANUS
NEPTUNE
PLUTO

SATURN
Perihelion
is on July 26

THE DEEP SKY

The celestial Swan, or Northern Cross, contains a host of wonderful deep-sky objects that often fall below the radar screen of backyard observers.



THE BLINKING PLANETARY appears vibrant in this Hubble image. In a small telescope, it blinks in and out of view depending on whether you use averted or direct vision. BRUCE BALICK (UNIVERSITY OF WASHINGTON), ET AL., AND NASA

Winging it in Cygnus

In the world of music, a lot of great tunes don't make the Top Ten. And so it is in the universe at large. This month we'll take a closer look at a number of charming objects in Cygnus the Swan that don't grab the deep-sky headlines.

One of the first objects observers learn to find is Albireo, a beautiful stellar pair consisting of a golden yellow and a blue sun that forms the head of the Swan. Another stunning colored pair lies just 5° west-northwest of 1st-magnitude Deneb, the brightest star in Cygnus. Omicron^1 (o^1) Cygni holds one thing over Albireo — it's obvious in binoculars and prominent at low power in a telescope. The brighter primary shows a fine yellow color that offsets the moderate blue hue of the secondary star, cataloged as 30 Cygni.

Through a telescope, a fainter third star creates a nice "hockey stick" asterism. Precise distance measurements from the European Space Agency's Hipparcos satellite show that none of the three stars is related.

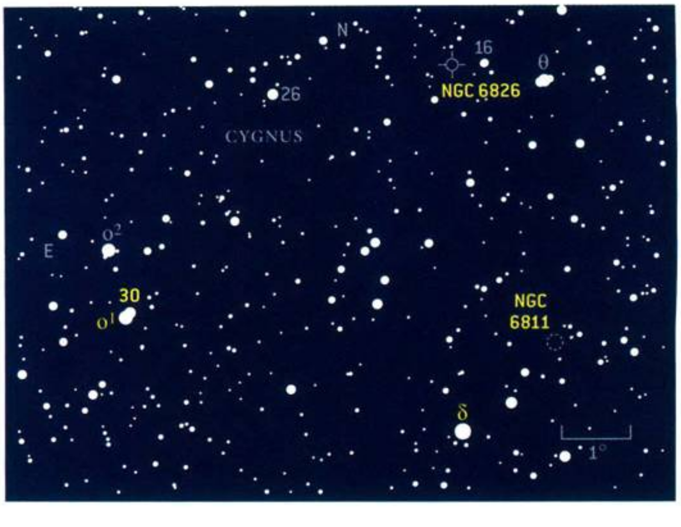
Although the constellation officially goes by the name "the Swan," many observers refer to Cygnus as the Northern Cross. At the end of the Cross's right arm, the bright star Delta (δ) Cygni turns out to be a binary. The pair, which takes 830 years to complete one orbit, is considered tough to split in a 3-inch scope, but modern 4-inch scopes make short work of separating the 6th-magnitude companion from its 2.9-magnitude primary. The 2.5″ gap between the two is a bit tighter than the ones that separate each of the pairs of the famous Double-Double next door in Lyra.

An easy 2° hop to the northwest of Delta will land you on the open star cluster NGC 6811. If you're under a dark sky, you'll see it in the finder scope as a misty glow. Although you won't be able to see it in a finder from the city, the cluster's bright stars show up easily in a 4-inch scope. Interestingly, no one seems to agree on how to describe NGC 6811. While some observers notice a bit of a hole in the middle, others see curving chains of stars resembling a human figure, and still other observers discern the Greek letter omega.

One of the sky's finest planetary nebulae is a snap to get to with an equatorial telescope. NGC 6826 floats 5.4° due north of Delta, where a modestly bright, roundish, gray-green glow surrounds an 11th-magnitude star. Crank up the power as high as the night and your scope allow. The nebula punches through city light pollution and moonglow quite well.

In telescopes smaller than 10 inches (25 cm) aperture, NGC 6826 behaves as its name implies: the Blinking Planetary. When you stare directly at it, the nebula disappears and all you see is the central star. But use averted vision, where you shift your view a tiny bit to let the light fall on the light-sensitive rods of your peripheral vision, and bingo — the glowing gas cloud instantly reappears.

In larger scopes, the nebula never fully disappears because the bigger mirror collects enough light to stimulate the cones, the color receptors of your central vision. No one argues that the nebula appears green. That particular hue comes from doubly ionized oxygen atoms.



Martin Ratcliffe *is former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist with Environment Canada.*

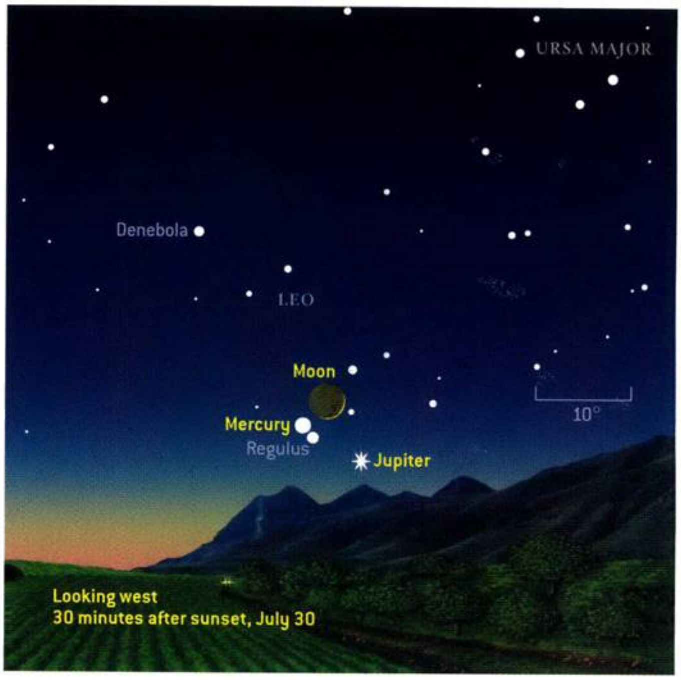
THE PLANETS

A long parade of planets — highlighted by the ever-improving Mars — gives dedicated observers a chance to view all the solar system's major worlds.

Mars hits the big time during July. The Red Planet more than doubles in brightness and reaches its largest apparent size in 15 years. This shining gem rises shortly before midnight and remains visible until dawn. Meanwhile, Jupiter lingers briefly above the western horizon after sunset, although not for long. By the end of July, it sets just 45 minutes after the Sun. For those interested in more challenging targets, a trio of distant planets — Uranus, Neptune, and Pluto — remains on view for most of the night.

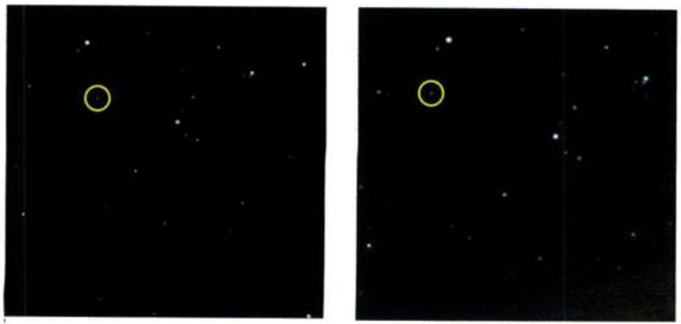
Let's start with a final look at the solar system's largest planet before it becomes hidden by sunlight. **Jupiter** lies in Leo the Lion, where it shines at magnitude −1.8, bright enough to pop out easily in the evening twilight. The crescent Moon joins Jupiter during the first two days of July. On the 2nd, Jupiter can be found less than 4° (approximately 8 moonwidths) below the three-day-old Moon. One evening later, focus your telescope on Jupiter to see the disk of Callisto and the shadow of Europa traverse the planet at the same time.

Mercury joins Jupiter toward the end of the month. On July 25, the two lie 0.4° apart in the bright twilight, close enough that both will appear in the same low-power telescopic field of view. You'll need a clear, unobstructed western horizon to see the planetary pair. Mercury then shines at magnitude −0.3, more than a full magnitude fainter than Jupiter. On July 30, the crescent Moon returns, standing 4° to the upper right of Mercury.



Looking west
30 minutes after sunset, July 30

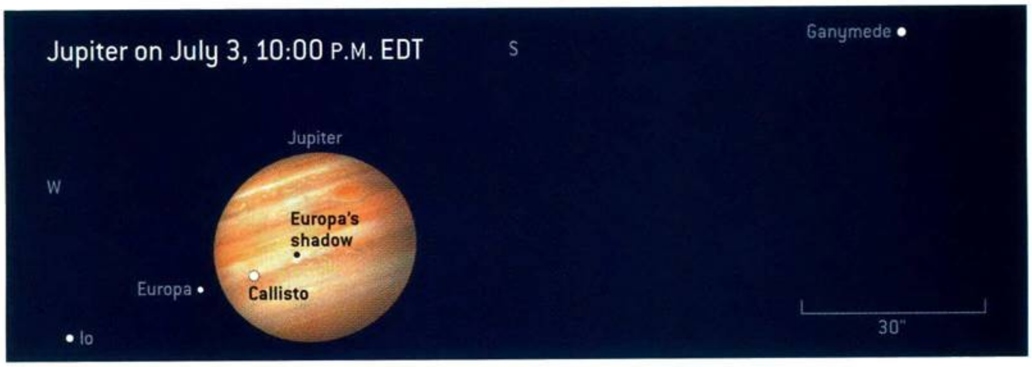
Moving farther east in the evening sky, **Pluto** is the next planet on display. Always very dim, Pluto represents the ultimate challenge for planetary observers. Although astronomers classify it as a major planet, they also consider it to be the largest of the trans-Neptunian objects, a group whose number now exceeds 600. Pluto reached opposition last month, so it remains visible until morning twilight starts to paint the sky. You'll need a detailed star chart to identify the 13.8-magnitude planet (see "Find the faintest planet" in the June issue). Pluto currently resides in Ophiuchus, some 2.3° north of the 2nd-magnitude star Eta (η) Ophiuchi.



PLUTO'S SLOW MOTION relative to the background stars gives away its identity. Here Pluto (inside the circle) slides beneath a brighter star between July 14 (left) and 17, 1993. PATRICK WIGGINS

Neptune proves far easier to spot. It rises around 10 P.M. local daylight time in early July and an hour earlier every two weeks after that. Neptune lies in Capricornus, just 1.5° west of 4th-magnitude Theta (θ) Capricorni, which lies in the upper middle of the constellation. The planet glows at magnitude 7.8, and its 2.3″-diameter disk and faint bluish tint can be spotted in most any telescope. Neptune will reach the peak of its current apparition at opposition in early August.

Glowing at magnitude 5.7, **Uranus** is an easy find in binoculars and can even be glimpsed with the naked eye under a dark sky. You'll need a telescope to discern its 3.7″-diameter disk, which shows a distinct blue-green color. Uranus lies in Aquarius, a little less than 4° south of 4th-magnitude Theta Aquarii. Like Neptune, it will reach opposition next month. Finder charts and tips for observing both Uranus and Neptune can be found in "Gunning for the gas giants" on page 86.


Jupiter on July 3, 10:00 P.M. EDT

All the early evening planets serve as a prelude to the big attraction of the month — **Mars**. In fact, Mars will remain the top story for the next few months. As July opens, the Red Planet rises in the east around midnight. It's easily the brightest object in Aquarius the Water-bearer and grows noticeably brighter with each passing week. On July 1, it shines impressively at magnitude –1.4, equivalent to Sirius, the brightest star in the sky. Within days Mars outshines this and reaches magnitude –2.3 by the 31st.

This rapid brightening of Mars (a difference of one magnitude corresponds to a factor of 2.5 times in brightness) goes hand in hand with a dramatic increase in its apparent size. July kicks off with Mars spanning 17″ — large enough for observers with even modest telescopes to see at least some detail. The 33-percent increase in size during July brings Mars past 22″ in diameter, the largest it's been since 1988, and it will continue to grow through August.

These striking changes result from Earth gaining on Mars in their respective orbits, bringing our two worlds closer. Earth travels in a smaller orbit that takes us around the Sun nearly 25 percent faster than Mars. We're just about set to overtake our ruddy neighbor.

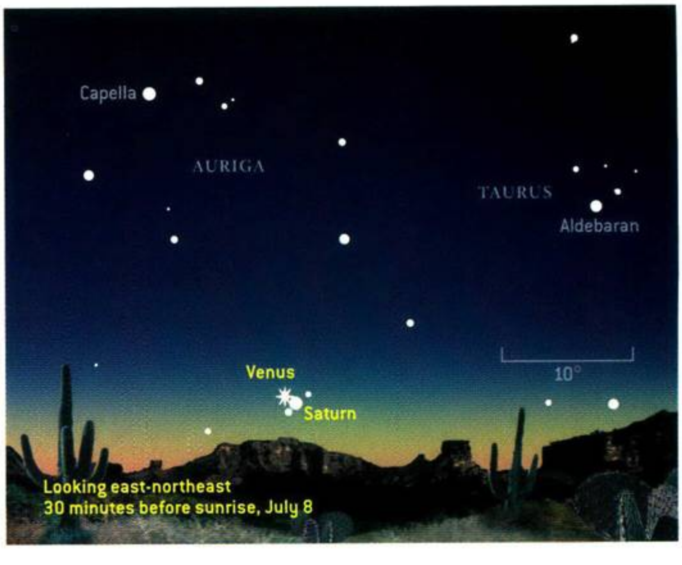
By the end of July, barring one of those dust storms that have an annoying habit of blanketing the entire planet near Mars's perihelion, plenty of detail should be visible to most observers. The southern hemisphere of Mars currently tilts in our direction, giving us a front-row seat to watch the south polar icecap recede as spring progresses south of its equator. On nights of good seeing, a wealth of dark surface markings should come into view as well. The two hours before morning twilight begins will be the best time to view Mars because it has then climbed higher in the sky for observers at mid-northern latitudes. Even better views await those in the Southern Hemisphere, where the Red Planet passes nearly overhead.

Each night, Mars moves eastward against the background stars, but that motion slows to a halt by July 30. Next month it begins a westerly track relative to the stars. This "retrograde motion," so-called because it runs opposite to the planet's normal eastward direction, occurs whenever Earth overtakes Mars. Mars makes its retrograde loop around the 4th-magnitude star Tau (τ) Aquarii, which lies less than 3° north-northwest of Delta (δ) Aquarii, also known by the name "Skat." Delta is also famous for its link to a July meteor shower (see "Meteors and Moons" on page 64).

A rare sight greets early risers on the morning of July 17. At 4 A.M. EDT (1 A.M. PDT), observers in North America will find the brilliant glow of Mars hanging just above the northern cusp of the waning gibbous Moon. People viewing from southern Florida will see a spectacular occultation as the Moon briefly hides the 20″-diameter disk of Mars.

In addition, shortly after the Moon rises on that same morning, observers east of the Rocky Mountains will see the Moon's bright limb occult Tau Aquarii. By the time the Moon comes up in the western half of the United States, viewers will see the faint star reappear from behind the Moon's dark limb.

The final two planets wait until dawn has started before putting in an appearance. **Venus** and **Saturn** lie within a degree of each other in the brightening twilight on July 8. They rise about 50 minutes before the Sun, so binoculars will be a big help in spying them before daylight swallows the duo. While Venus is currently wrapping up a long morning apparition and will soon disappear in the Sun's glow, Saturn is starting to climb higher in the sky and will offer improving views through the end of the year.


Looking east-northeast
30 minutes before sunrise, July 8

METEORS AND MOONS

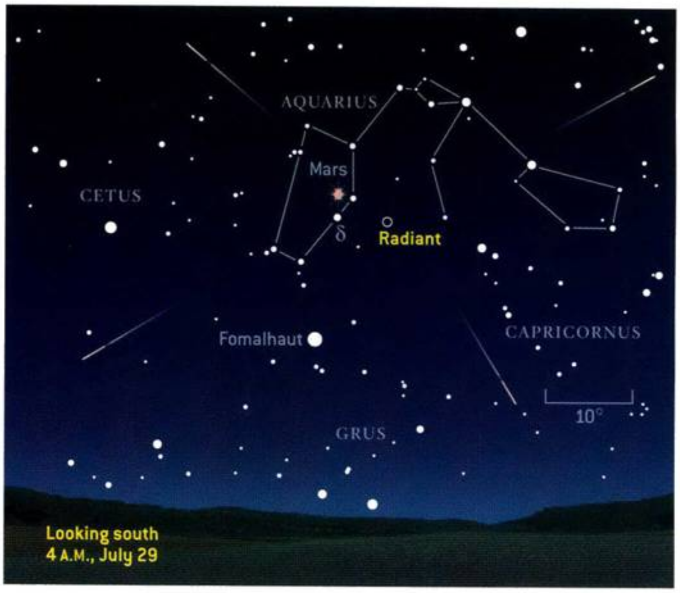
A trio of less-than-stunning meteor showers vie for attention this month; meanwhile, a flooded lunar crater flashes into prominence around First Quarter Moon.

Find a meteor's origin

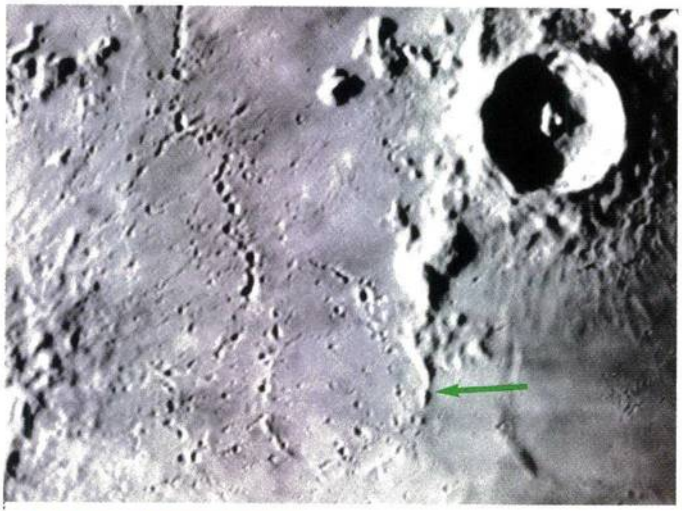
The Southern Delta Aquarid meteor shower usually takes top honors in July, and 2003 is no exception. The radiant of this shower lies near the star Skat (Delta [δ] Aquarii), which currently sits just south of Mars. The shower begins on July 12, with its peak predicted for July 29. That's the day of New Moon, so observing circumstances couldn't be better. The meteors belonging to this shower have modest speeds and usually appear faint, with observers typically reporting between ten and twenty meteors per hour from dark sites.

Another minor shower, the Alpha Capricornids, stands out because it produces occasional fireballs. Activity lasts from July 3 to August 15 and peaks on the morning of July 30 — again during the dark of the Moon. Capricornus lies fairly low in the south, so any meteors seen from northern latitudes tend to have long trails. The long trails and fireball potential make this shower worth watching.

The final "minor" meteor shower this month is actually a major shower seen a month before its peak. The Perseids dominate the August meteor scene, but activity actually begins in mid-July. The slow build-up to the August peak can be viewed best in late July, when the Moon's out of the way. The morning hours, when the shower's host constellation, Perseus the Hero, appears higher in the sky, are the best time to view. With so many showers active during late July, have some fun by trying to identify which shower each meteor belongs to.



Looking south
4 A.M., July 29


THE FLOODED CRATER STADIUS [arrow], located just southwest of Eratosthenes, stands out when sunlight hits it at a grazing angle. GÉRARD THERIN

Moon feature: Stadius

A remarkable submerged crater sits southwest of Eratosthenes and east of Copernicus, bordering the region called Sinus Aestuum. The crater is called Stadius after the 16th-century Belgian astronomer and mathematician Jan Stade. Its low, broken walls stand in stark contrast to the prominent craters flanking it. The region comes into view on July 8/9, shortly after First Quarter phase.

Stadius measures 43 miles (69 km) wide and its highest walls, standing 2,000 feet tall, lie on the northeastern rim. Look for the many crater pits that dot its floor. A complex chain of mountains seems to connect Stadius to Eratosthenes, although these craters formed at very different epochs. A remarkable chain of tiny craters extends north and a little west from Stadius. These and a host of other subtle features on the surrounding plain can be seen as the Sun rises over the region. Gentle ridges stand out with the Sun at low illumination angles, and many crisscross the lava plains. Indeed, the low relief of Stadius and its surroundings mean sunrise (just after First Quarter phase) and sunset (just after Last Quarter phase) are the only times these features stand out.

If you head about three crater diameters south of Stadius, you'll find the 7.6-mile (12.2-km)-wide crater Gambart C. It was slightly northeast of this crater that the Surveyor 2 spacecraft crashed into the Moon on September 22, 1966, after one of its engines failed to ignite.

COMETS AND ASTEROIDS

Asteroid Vesta remains a cinch to find in the early evening sky, while a fainter periodic comet guns for its share of recognition at the midnight hour.

Gunn grazes globular

Thanks to the world wide web, observers can get breaking news of bright but short-lived comets. For news flashes on all the latest comets, check out http://encke.jpl.nasa.gov.

While we always have our fingers crossed for an unexpected comet to brighten, this month you'll need to push yourself for a peek at a frozen snowball of dirt and ice. Pick a time around New Moon July 28/29) to avoid the glaring light of our natural satellite and find a dark country site — you're unlikely ever to see periodic comet 65P/Gunn from the city.

Wait until midnight for Sagittarius to rise above the horizon murk and zero in on the base of the Teapot asterism. You'll probably need an 8-inch telescope to find the small, roundish blob that is the comet, glowing at 12th magnitude. Bump the power past 100x to darken the background sky and enlarge the apparent size of the comet.

Astrophotographers should take note that on the night of July 1/2, Comet 65P/Gunn grazes the northern edge of the globular star cluster M70, making a nice photo opportunity. A greater challenge will be to grab a shot on the 10th, when the comet passes close to the globular NGC 6652, because the bright Moon will be near.

The next decent comet astronomers are aware of is periodic comet 2P/Encke, which will brighten into a nice evening object in late October and November.

/// JULY COMET POSITIONS

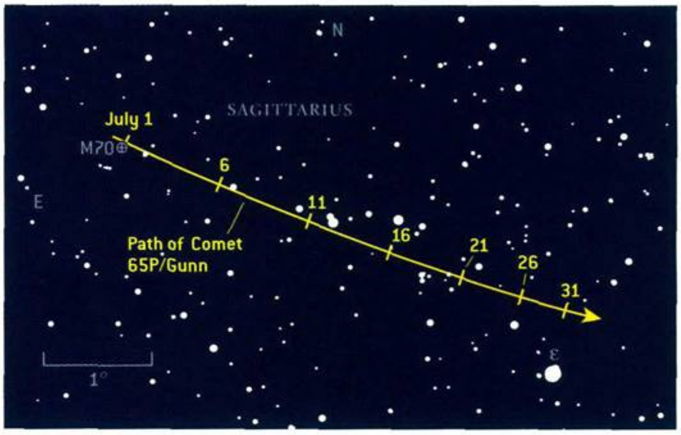
COMET 65P/GUNN

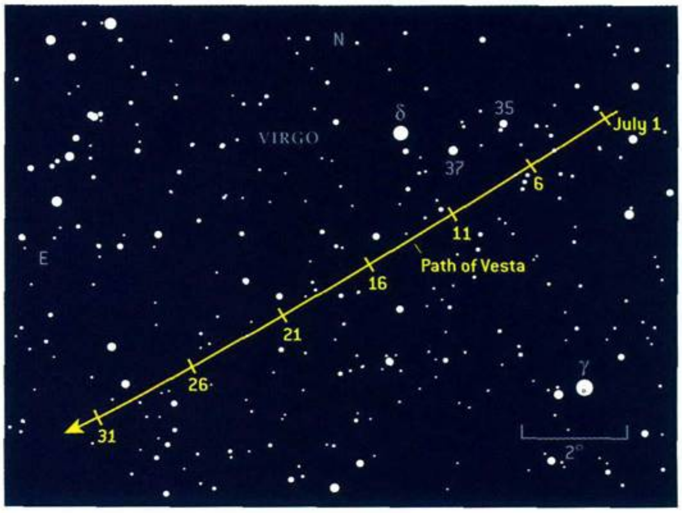
{Date}	{R.A.}	{Dec.}
July 1	18h43.0m	−32°15'
July 6	18h39.0m	−32°40'
July 11	18h35.1m	−33°00'
July 16	18h31.5m	−33°18'
July 21	18h28.3m	−33°31'
July 26	18h25.7m	−33°41'
July 31	18h23.7m	−33°48'

/// JULY ASTEROID POSITIONS

ASTEROID 4 VESTA

{Date}	{R.A.}	{Dec.}
July 1	12h40.2m	3°40'
July 6	12h45.8m	2°46'
July 11	12h51.7m	1°50'
July 16	12h57.9m	0°54'
July 21	13h04.5m	−0°04'
July 26	13h11.4m	−1°03'
July 31	13h18.5m	−2°02'





Vesta winds down

If you've been following the asteroid 4 Vesta for the past few months, it won't take long to find now. Step outside with binoculars, aim to the upper right of the bright star Spica in Virgo, lock onto a couple of guide stars, and sweep it up.

If this is your first time hunting space rocks, the strange neighborhood will take longer to navigate, but we'll get you there. First find 1st-magnitude Spica on the fold-out map, toward the horizon on the right side (west). Then locate the two stars Gamma (γ) and Delta (δ) Virginis, which will serve as your guides.

Take the map outside and match it against the night sky. Spica will be the bright blue-white star located above the southwestern horizon. Slowly scan your binoculars up and down between Gamma and Delta, and compare the view with the chart above. Depending on the specs of your binoculars, you might just be able to fit both stars in at the same time.

Use the fainter stars on the chart to pin down which point of light is Vesta. At magnitude 7.5, it might be a little faint for binocular users in the city. Avoid searching for it from July 4 to 7, when the Moon lies nearby and throws glare into the sky. **A**

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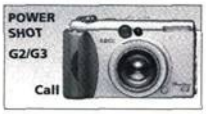

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Laser eye surgery, the star Mira, meteoroid vs. asteroid

LASER EYE SURGERY

For stargazing, does radial keratotomy or Lasik surgery produce a positive effect on one's perception of the stars? My concern is that a pinpoint source of light such as a star will reveal the concentric circles of lens material removed by the laser. Is this possible?

— **J. CHRISTOPHER FAULKNER,** BIRMINGHAM, ALABAMA

BEING ABLE TO SEE PINPOINT STAR IMAGES in star clusters like the Pleiades and elsewhere in the sky demands the most of Lasik eye surgery. GEORGE GREANEY

Radial keratotomy is an older procedure that involves creating a series of radial cuts into the cornea (the curved front surface of the eye) to change its shape. The cuts are made using a scalpel and come quite close to the center of the cornea, resulting in thin, linear scars. While often not a problem in daylight, these scars can cause glare and halos at night. Point sources of light like stars or distant streetlights show a starburst effect. In addition, the scars distort the cornea slightly, reducing its ability to sharply focus light.

Lasik (Laser-Assisted In-Situ Keratamileusis), on the other hand, reshapes the cornea by using an ultraviolet laser to evaporate corneal tissue. This is done in a circular zone centered over the pupil after a thin slice of outer cornea has been moved out of the way. Scarring rarely occurs, and the cornea can be reshaped accurately to eliminate dependence on glasses for viewing objects at a distance.

While Lasik usually provides clear day and night vision in most people, amateur astronomers have especially high demands for clear night vision. Most amateur astronomers I know who have had the procedure are very happy with the results. None of them report seeing bad effects from the concentric rings of corneal tissue removed. But everybody's eyes and visual demands are unique, so you should consider a few relevant facts before surgery.

First, the treatment zone usually measures 6 millimeters in diameter. This is somewhat smaller than the pupil of a dark-adapted eye in a young person. There's a slight chance that this might cause halos, glare, and decreased contrast to vision at night. However, the laser programs are good at smoothing the junction to help decrease these effects. A second effect of Lasik is it can actually increase the higher order optical errors (like spherical aberration) in people who are initially very nearsighted. This too may result in decreased contrast, especially at night. For these people, waiting for wavefront-assisted Lasik or other refractive surgical procedures may be a better choice because these will be able to correct the higher order errors of vision as well as nearsightedness.

Lasik can be very effective for amateur astronomers. However, it is important for anyone considering refractive surgery to discuss their concerns with an experienced surgeon or qualified eye-care provider. Readers wanting more information can reach me at the email address below. — **MYRON E. WASIUTA,** O.D., F.V.A.O.; DIRECTOR OF OPTOMETRY, COLEMAN EYE ASSOCIATES; MWASIUTA@MWC.EDU

THE STAR MIRA

I live on the coast of Maine, and following the "Christmas Blizzard" of 2002, I was out cross-country skiing at night and tried to identify the fainter constellations and stars toward the southwest. My star chart indicated a star called Mira in the constellation Cetus. I could identify most of the stars in Cetus, but I could not *pinpoint this one. Why?*

— **ROBERT HARDY,** LAMOINE, MAINE

You couldn't see Mira (Omicron Ceti) in late December 2002 because it was then much dimmer than the naked eye can see. Mira is a long-period variable star that cycles between about magnitude 3 and magnitude 9 every 331 days, on average. In its most recent cycle, Mira dropped below 6th magnitude in late November 2002. It bottomed out in early March 2003 and should climb back to peak brightness again in late June or early July 2003.

Because Mira isn't always visible, star charts often show Mira as a hollow circle with a diameter corresponding to its average magnitude at maximum light.

Mira's variability was first noticed by Dutch astronomer-clergyman David Fabricius, who observed it at 3rd magnitude in August 1596. A few months later it was no longer visible, and Fabricius could find no record of the star on any astronomical charts or globes.

Unaware of Fabricius's observations, celestial cartographer Johann Bayer included the star in his 1603 star atlas, *Uranometria*, plotting it at 4th magnitude and labeling it Omicron (o). Although Fabricius again noted the star at 3rd magnitude in February 1609, it wasn't until 1638 that another Dutch astronomer, Phocylides Holwarda, established that its brightness varied in a regular manner. Finally, writing about the star in 1662, Johannes Hevelius gave it the name it now bears.

Mira is the prototype of a large class of stars called long-period variables. These are old, reddish stars about as massive as the Sun that slowly pulsate like a giant heart. As a Mira-type star grows in size, it cools and fades; thus Mira is brightest when smallest. Yet even at minimum size, Mira is so large that if it replaced the Sun, Earth would be orbiting well below the star's surface.

A stage of pulsating variability like Mira's probably awaits every star that has about the same mass as the Sun. After millions of years as a Mira-type variable, during which much of the star's material is driven off into space, these stars will evolve into white dwarfs — tiny white-hot stellar remnants. — **ROBERT BURNHAM,** CONTRIBUTING EDITOR

PIECES OF SOLAR SYSTEM DEBRIS known as meteoroids give birth to the streaks of light we call meteors when they slam into Earth's atmosphere and get incinerated. JOHN CHUMACK

METEOROID VS. ASTEROID

What size distinguishes a meteoroid from an asteroid? — **PHIL BIGELOW,** BELLINGHAM, WASHINGTON

That's an interesting question. Meteoroids and asteroids belong to a collection of bodies, including planets and comets, that are "naturally formed objects orbiting the Sun." The differences between these things are largely historical and, to some extent, arbitrary.

Planets and comets were recorded in the earliest documents of human civilization. Then Ceres was discovered in 1801. Because it was so much smaller than the known planets, it was placed in a special category — asteroids — created to distinguish it from planets (which are large) and comets (which visibly outgas).

During the 1800s, a scientific consensus developed that meteorites and meteors indeed come from outer space and probably were small fragments of asteroids and comets. But in those days the known asteroids were so much larger than meteorites that astronomers concluded meteorites must be coming from vastly smaller bodies orbiting the Sun. These bodies had to be about a few meters (yards) in diameter and were probably fragments of asteroids and comets. So another special term was invented, *meteoroid*, for objects that orbited the Sun but were too small to be seen with a telescope.

The problem comes, as it often does, from rapidly advancing technology. Asteroid searches now regularly find and track objects that are as small as a few meters in diameter, small enough to be the direct source material for meteorites. But any object found by a search program is automatically treated as an asteroid (or a comet). So functionally there is no longer a specific size that distinguishes a meteoroid from an asteroid.

An asteroid is something that can be tracked by a telescope. Meteoroids are all those small objects that we know *must* be out there but are still too small to be tracked by a telescope. As the size of newly discovered asteroids gets smaller, the term *meteoroid* becomes increasingly archaic and irrelevant.

So the short answer is: If you can see it, it's an asteroid. If you can't see it, it's a meteoroid. —**DAN BRITT,** UNIVERSITY OF CENTRAL FLORIDA

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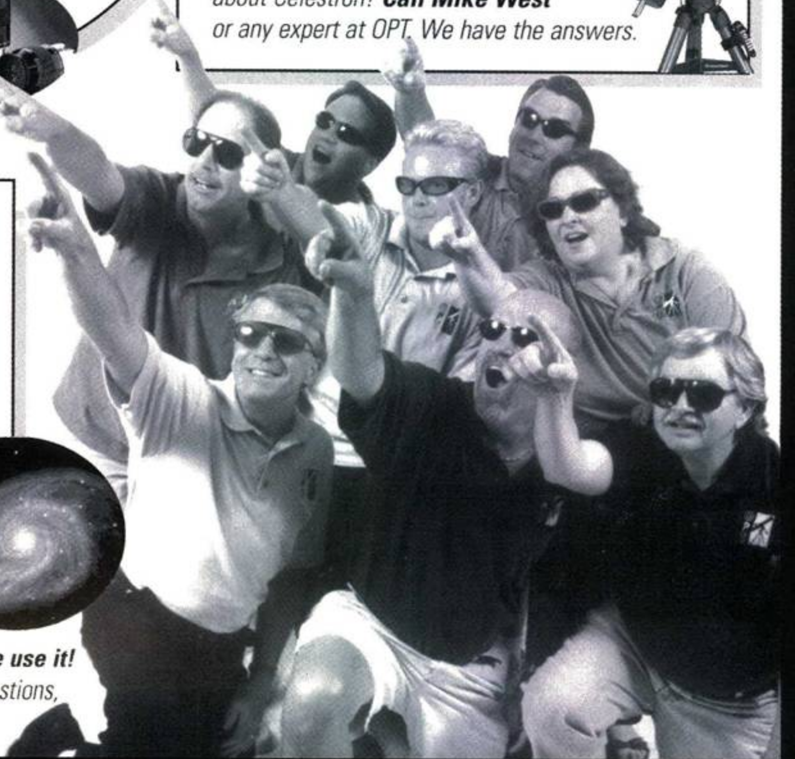

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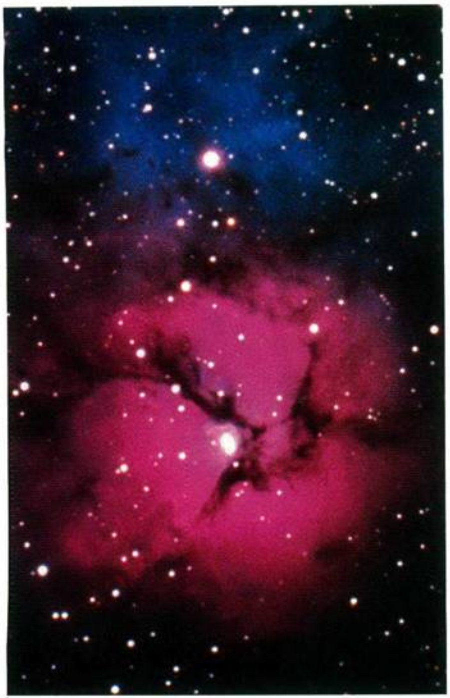
Sagittarius

Sagittarius holds the heart of the galaxy, and with it, a bounty of Milky Way star clouds, clusters, and nebulae. /// BY TOM POLAKIS

On warm summer nights, it's irresistible to gaze toward the center of our galaxy within the great constellation Sagittarius the Archer. Loaded with star clouds, clusters, and bright and dark nebulae, the constellation could easily keep a telescopic observer busy for an entire observing season. ☾ Before diving in with the telescope, though, it's worth spending some time discussing what Sagittarius offers unaided eyes. The most prominent pattern in the constellation is the Teapot, an asterism of eight 2nd- and 3rd-magnitude stars that resembles its namesake. The Teapot's stars range in distance from 80 to 300 light-years. At the top of the Teapot is Lambda (λ) Sagittarii, the asterism's closest star, while Delta (δ) Sagittarii is its most distant and nearly 20 times as luminous as Lambda. It's easy to think of the Teapot as occupying most of the constellation's area, but in fact, Sagittarius is several times larger.



M20 (THE TRIFID NEBULA) appears to be split into sections by dark dust lanes. TONY HALLAS

The real beauty of Sagittarius lies in the brilliant star clouds of the summer Milky Way. From a suburban site, the star clouds resemble steam emanating from the spout of the Teapot. Their glow ends abruptly toward the northwest into the darkness of the Milky Way's Great Rift. The high point is the Large Sagittarius Star Cloud, a glowing oval 4° long. Working north and east, we come across the Lagoon Nebula and the Small Sagittarius Star Cloud. From a good observing site, the width of the galaxy's bulge approaches 45° in this region. The entire Teapot is filled with the radiance of countless stars. To the east of the Teapot, the star density drops off dramatically to herald the arrival of the autumn sky.

The galaxy's center lies just barely in the confines of Sagittarius. The constellation's western extreme, where it meets Ophiuchus and Scorpius, contains a nondescript region extinguished from view by intervening dust clouds. Here lies Sagittarius A* (pronounced "A star"), a strong radio point source. In 1954, astronomers realized the association between this source and the Milky Way's center. Today, they believe a black hole of several million solar masses exists at Sagittarius A*'s location.

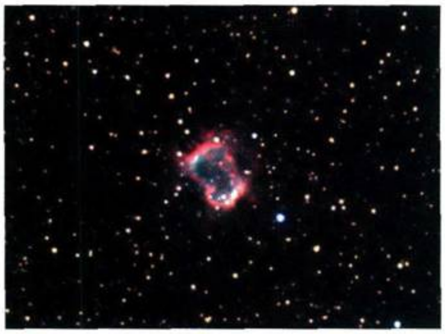
Starting at Gamma (γ) Sagittarii at the tip of the Teapot's spout, it is an easy starhop to our first object. Pan a half degree northwest to find the globular cluster **NGC 6522**. A region of low obscuration known as Baade's Window enables us to see this cluster, which lies 90 percent of the way to our galaxy's center. Dynamical studies of its motion suggest this globular never strays more than 5,000 light-years from the center of the galaxy. A 12-inch telescope will resolve several dozen stars in a 3′ ball centered on a strongly concentrated core. Look for a slightly brighter interloper star on the cluster's eastern edge. A pleasing sight is the pairing of NGC 6522 with another globular cluster, NGC 6528, just 16′ to the east. This small cluster is less impressive, though, barely revealing individual stars even in a large light bucket.

As we pan a couple degrees northward, we come across the heart of the Large Sagittarius Star Cloud, which is bright but only partially resolved through the telescope. Keep going until you get to

NGC 6520 AND B86 show opposites really do attract. The open cluster and Bok Globule stand out in the star-filled Milky Way sky. JACK MARLING

NGC 6520, a well-defined open cluster against a bright background of distant stars. In an 8-inch telescope, 30 stars of magnitudes 10 and 11 are tightly compressed into a circle only 4′ in diameter. The distance to these stars is only 5,000 light-years, less than one-fifth of the way to the galactic center.

NGC 6520 is tightly paired with one of the sky's most distinct dark nebulae.



NGC 6445 is an unusually shaped planetary nebula that is sometimes called the Box Nebula. RAY AND GEOFF WEAVILL/ADAM BLOCK/NOAO/AURA/NSF

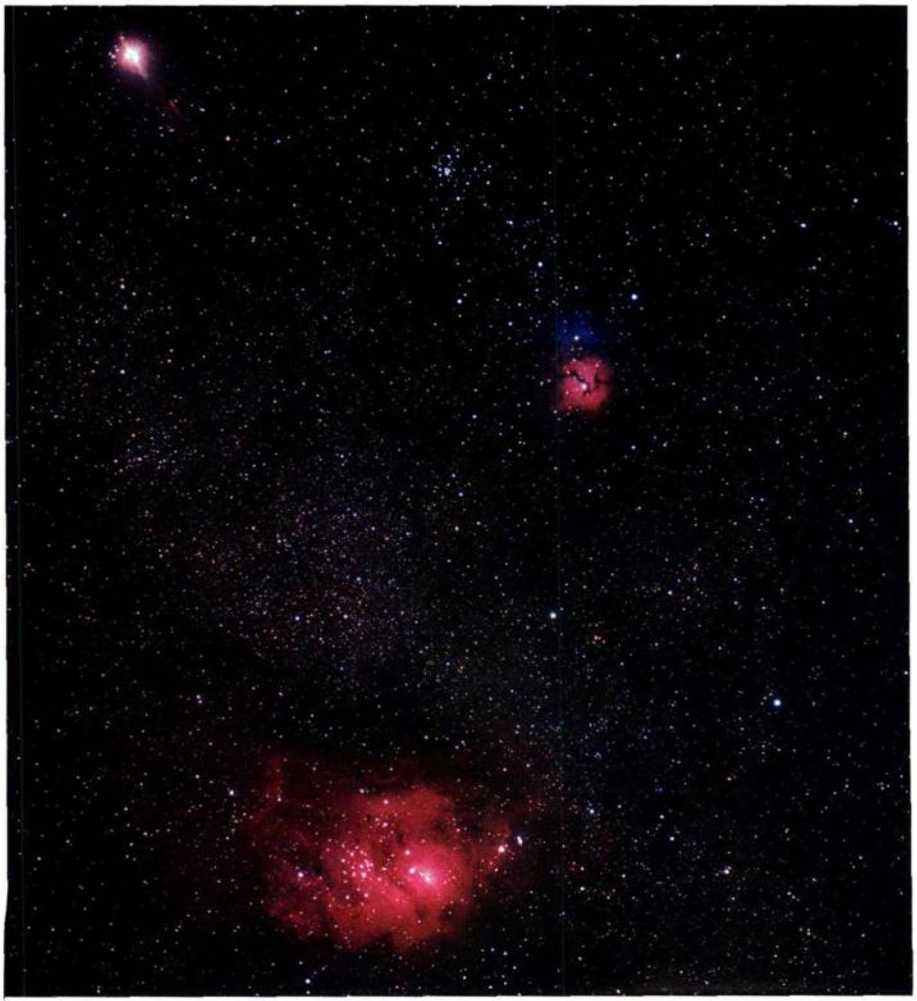
Barnard 86 is a Bok Globule about one-tenth as distant as its "companion" open cluster. Its starless, irregular form stands out against a myriad of faint stars. The scene resembles that of a cumulus cloud floating in a summer sky. An orange 7th-magnitude star on the globule's western edge accents the view in superb fashion.

No less than 15 Messier objects lie within Sagittarius. One of the finest is **M8** (**NGC 6523**), the Lagoon Nebula. Easily visible with unaided vision from a dark site, it spans a half degree and is especially enhanced by a nebula filter. Embedded within the nebula is the open cluster NGC 6530, where 35 stars brighter than 11th magnitude stand out well in a region 8′ across. The cluster is surrounded by faint nebulosity that is cut down the middle by a dark lane. Immediately to the west of this lane lies 8th-magnitude 9 Sagittarii, the star responsible for exciting the nebula and making it glow. Farther west is the nebula's heart, a region of intense brightness about 5′ across. Look for the Hourglass Nebula, which, like the Orion Nebula, is known for its collection of very young stars.

M8 is paired with another interesting object. A small refractor provides the most pleasing view of **M20** (**NGC 6514**), the Trifid Nebula, in the same field as the Lagoon. The Trifid owes its name to three lanes of dust in front of the emission nebula that seem to converge at its center. Visually, it appears about 10′ across and is best viewed at medium magnifications. Look for a nice triple-star system just to the west of the center. All three are part of the physical system of five ionizing stars situated with the nebula some 5,500 light-years away. Removing the nebula filter, the reflection nebula to the north comes into view, increasing the size of M20. The nebula shines by reflected light from the bluish 9th-magnitude star in the center.

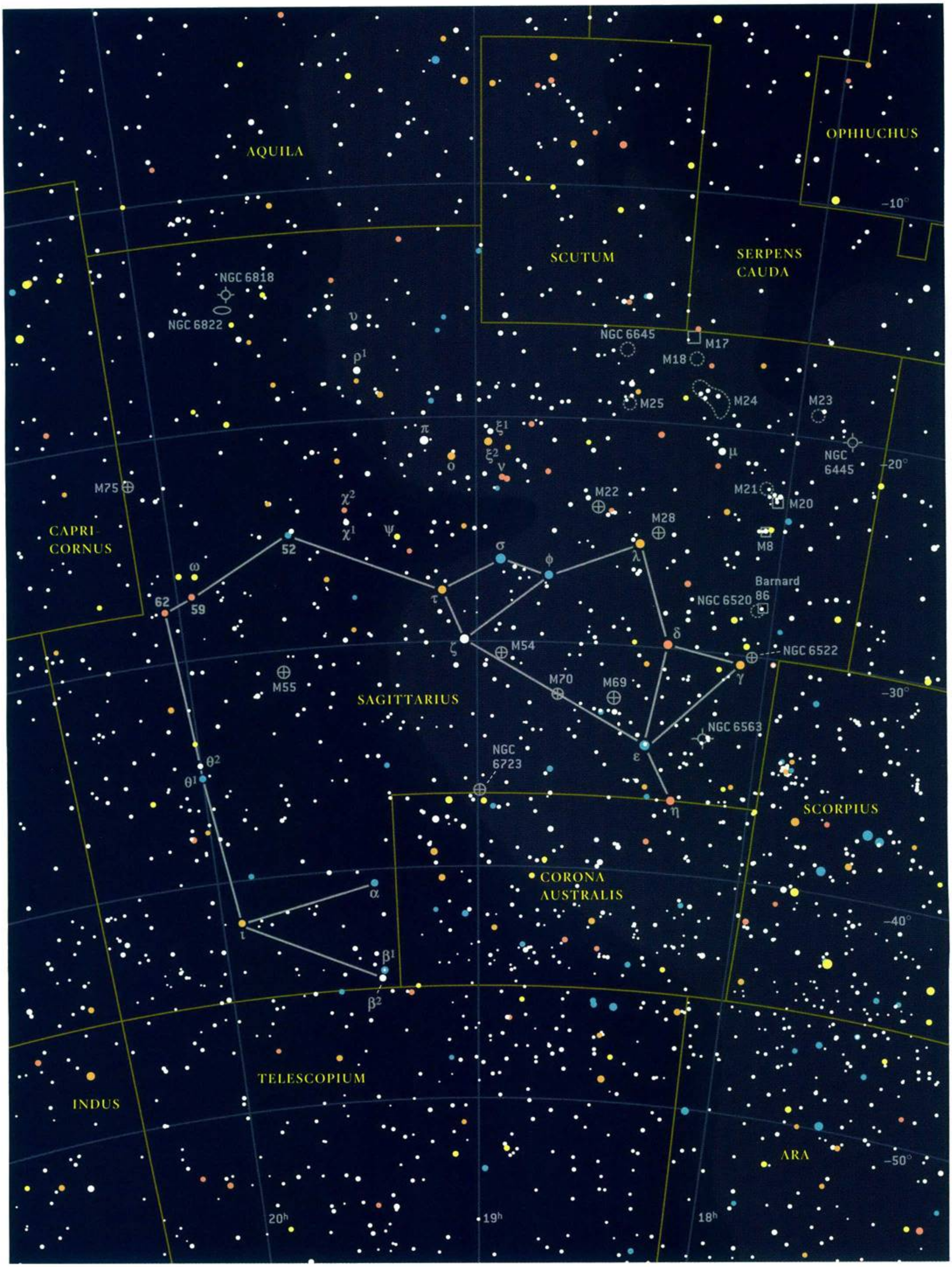
Less than 1° to the northeast sits the small open cluster **M21** (**NGC 6531**). A 6-inch scope shows several dozen stars brighter than 12th magnitude scattered over a region 7′ across. An 8th-magnitude star shines at the cluster's center.

NGC 6445 is a bipolar planetary nebula that shows up readily in modest telescopes. With a magnification of 200x, my 13-inch scope shows a dark center and two lobes to the northwest and southeast. The entire object appears about 30″ across. Larger telescopes show the planetary as having a thin, rectangular shape and a large, dark central void. Just 20′ to the south lies the globular cluster NGC 6440, a 2′-diameter, concentrated haze



M8, M20, AND M21 form a lovely trio. The Lagoon Nebula (bottom) holds the open cluster NGC 6530, while another open cluster, M21 (top center), lies northeast of the Trifid Nebula. TONY AND DAPHNE HALLAS

Tom Polakis *is an aerospace engineer in Tempe, Arizona. He enjoys deep-sky observing and astrophotography.*


AQUILA
SCUTUM
OPHIUCHUS
SERPENS CAUDA
-10°
NGC 6818
NGC 6822
υ
ρ¹
NGC 6645
M17
M18
M25
M24
M23
π
ξ¹
ξ²
ο
ν
μ
NGC 6445
-20°
M75
M22
M21
M20
χ²
χ¹
ψ
M28
M8
CAPRICORNUS
52
σ
φ
λ
ω
62
59
τ
Barnard 86
NGC 6520
ζ
M54
δ
NGC 6522
M55
SAGITTARIUS
M70
M69
γ
-30°
NGC 6563
ε
NGC 6723
θ²
θ¹
η
SCORPIUS
CORONA AUSTRALIS
α
-40°
ι
β¹
β²
TELESCOPIUM
INDUS
ARA
-50°
20ʰ
19ʰ
18ʰ

with only the slightest hints of resolution in large telescopes.

Situated 2,500 light-years away in the northwestern corner of Sagittarius is **M23 (NGC 6494)**. This open cluster shows up clearly in an 11x80mm finder scope and faintly to the naked eye at a dark site. In an 8-inch scope at 100x, M23 shows 80 stars brighter than 13th magnitude. It is well detached from a moderately rich surrounding field. Look for a chain of eight stars dangling toward the northwest to a 7th-magnitude star that's detached from the cluster.

Few objects are as well-defined as **M17 (NGC 6618)**, the Omega Nebula (also called the Swan). In a 6-inch telescope, it appears as a bright bar 7′ long with a short extension from the west end to the south. Higher magnifications reveal this feature to be hook-shaped, with a dark center created by obscuring material. Notice how much darker the sky appears inside this hook than in the rest of the field. In a 12-inch, the length of the bar is scalloped into fine striations, and additional nebulosity becomes visible out to a length of 10′. Although an unfiltered view provides the best aesthetic appeal, a nebula filter brings out the object's true extent. At a distance of 7,000 light-years, M17 is one of the Milky Way's most luminous HII regions. But the stars that excite the nebula are difficult to observe because they are hidden deep inside.

M18 (NGC 6613) can be found 1° south of the Omega Nebula. Containing about a dozen 9th- and 10th-magnitude stars across its 7′ diameter, M18 is one of the least impressive Messier objects. The best views of this cluster seem to be in small scopes at low magnification. Larger aperture and power simply don't reveal any more depth to this star-poor cluster.

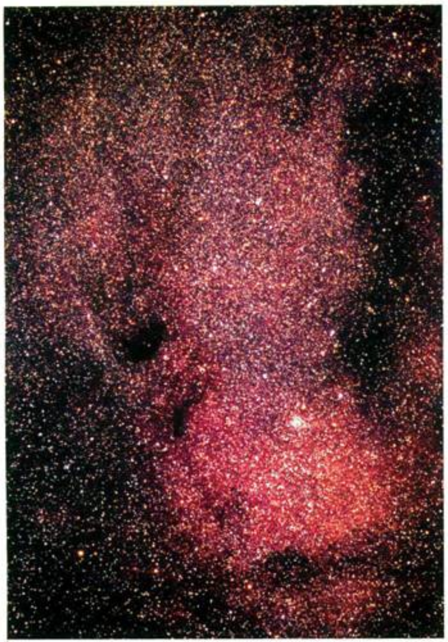
An oddity on Charles Messier's list, **M24 (IC 4715)** is the only star cloud in the catalog. An interstellar window enables us to see this swarming mass of stars halfway to our galaxy's center. Known also as the Small Sagittarius Star Cloud, it is nearly 2° long and a third as wide, appearing to the unaided eye as one of *the Milky Way's* brightest regions. A wide-field instrument reveals its true splendor. The field contains wall-to-wall stars against a bright backdrop of more distant suns. Toward the northwest end of the star cloud is NGC 6603, a magnif-

M17 (THE OMEGA NEBULA) is often called the Swan Nebula for the shape of its brightest region. Radiation from stars hidden in M17 set the nebula ablaze. BILL AND SALLY FLETCHER

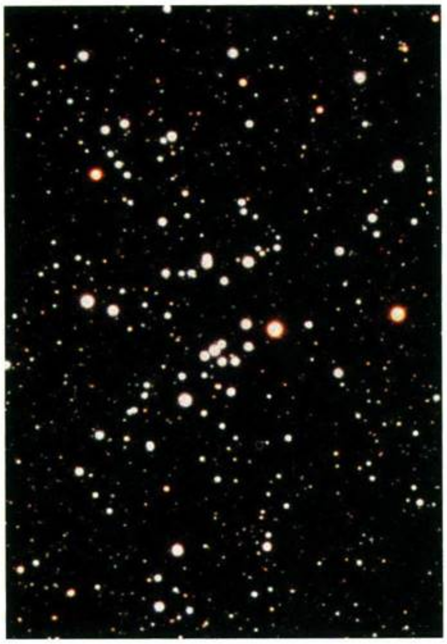
/// Deep-Sky Objects in Sagittarius

OBJECT	R. A.	DEC.	MAG.	SIZE	TYPE	NOTES
NGC 6445	17h49.2m	–20°01'	11.2	34"	PN	—
M23 (NGC 6494)	17h56.8m	–19°01'	5.5	27'	OC	—
M20 (NGC 6514)	18h02.3m	–23°02'	—	20' by 20'	BN	Trifid Nebula
Barnard 86	18h03.0m	–27°53'	—	5' by 5'	DN	—
NGC 6520	18h03.4m	–27°54'	7.6	6'	OC	—
NGC 6522	18h03.6m	–30°02'	8.4	5.6'	GC	—
M8 (NGC 6523)	18h03.8m	–24°23'	—	45' by 30'	BN	Lagoon Nebula
M21 (NGC 6531)	18h04.6m	–22°30'	5.9	13'	OC	—
NGC 6563	18h12.0m	–33°52'	11.0	48"	PN	—
M24 (IC 4715)	18h16.5m	–18°50'	4.6	95' by 35'	STAR CLOUD	Small Sagittarius Star Cloud
M18 (NGC 6613)	18h19.9m	–17°08'	6.9	10'	OC	—
M17 (NGC 6618)	18h20.8m	–16°11'	—	20' by 15'	BN	Omega, or Swan, Nebula
M28 (NGC 6626)	18h24.5m	–24°52'	6.8	11.2'	GC	—
M69 (NGC 6637)	18h31.4m	–32°21'	7.6	7.1'	GC	—
M25 (IC 4725)	18h31.6m	–19°15'	4.6	32'	OC	—
NGC 6645	18h32.6m	–16°54'	8.5	10'	OC	—
M22 (NGC 6656)	18h36.4m	–23°54'	5.1	24'	GC	—
M70 (NGC 6681)	18h43.2m	–32°18'	8.0	7.8'	GC	—
M54 (NGC 6715)	18h55.1m	–30°29'	7.6	9.1'	GC	—
NGC 6723	18h59.6m	–36°38'	7.2	11.0'	GC	—
M55 (NGC 6809)	19h40.0m	–30°58'	6.4	19.0'	GC	—
NGC 6818	19h44.0m	–14°09'	9.3	17"	PN	Little Gem Nebula
NGC 6822	19h44.9m	–14°48'	8.8	19.1' by 14.9'	Gal	Barnard's Galaxy
M75 (NGC 6864)	20h06.1m	–21°55'	8.5	6'	GC	—

Object: Designation in NGC or other catalog. **R. A. and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size:** Size in arcminutes or arcseconds.



M24, the Small Sagittarius Star Cloud, includes the open cluster NGC 6603 and dark nebulae Barnard 92 and 93. MICHAEL STECKER



M25 is an open cluster about 2,000 light-years away. A dark gap seems to separate its central stars into two bands. MICHAEL STECKER

icent open cluster of several dozen stars packed into a 4′ diameter. On the northwest edge is Barnard 92, a prominent, small, dark nebula shaped like a fingerprint. In 1913, E. E. Barnard used visual observations of this dark nebula through the great telescopes of the time to postulate that dark nebulae are not holes in the heavens but obscuring foreground clouds. See if you can duplicate his observations; the light of one 11th-magnitude star shines at its center.

Another naked-eye cluster in Messier's list, **M25** (**IC 4725**) is a rich cluster showing 60 members in a 20′ field to a 13-inch scope. Two chains of stars near the center are divided by a starless gap. In the northern chain lies U Sagittarii, a cluster member that was found to be a Cepheid variable in 1925. Many of the cluster members are brighter than 11th magnitude, making this a nice sight in small telescopes. At the northwest edge is a yellow star of magnitude 7. Located 2,000 light-years away, the cluster is set well apart from the starry background.

Move the scope 2° north of M25 to discover **NGC 6645**, another fine open cluster. This one requires a bit more aperture to appreciate. My 20-inch scope shows 60 stars of mostly 11th and 12th magnitudes crowded into a 7′ field. Near the center of the cluster is an obvious chain of a dozen stars whose center is devoid of stars.

The globular cluster **M28** (**NGC 6626**) is situated at a tight radius from the Milky Way's center. It is easily swept up 1° northwest of Lambda Sagittarii. Its stars are as bright as magnitude 12, which means it resolves well in modest instruments. A 13-inch shows nearly 100 suns clearly resolved across the bright center. At 250x, the fall-off from the core creates a magnificent three-dimensional effect. Look for two star chains that extend to the north.

A line from Tau (τ) through Sigma (σ) Sagittarii points to the great globular cluster **M22** (**NGC 6656**), which lies only 9,000 light-years away. Among globulars, it is exceeded in brightness by only Omega Centauri and 47 Tucanae. It is one of only four globulars containing stars brighter than 11th magnitude. Due to its closeness and bright stellar members, the cluster appears large and fully resolved through a telescope. In a 6-inch scope, dozens of stars shine within an area more than 10′ across that is centered on the cluster's broadly concentrated core. A large Newtonian doubles the apparent size and reveals hundreds of stars; the quantity is limited by seeing conditions. The surrounding star field is very rich, creating a bright background for the scene.

Advanced observers have taken to searching in M22 for GJJC1, one of only four planetary nebulae known in a globular star cluster. The handful of observers who have succeeded in seeing the whole nebula note that high magnification and a good finder chart are required.

Next, we begin a west-to-east sweep across the base of the Teapot. **NGC 6563** is a planetary nebula that shows up at 200x as a ghostly disk in an 8-inch telescope. It is easily found by "blinking" the field with a nebula filter, but be sure to remove the nebula filter for the high-power view. In my 20-inch scope, I can see a 40″ uniform disk with very slight east-west elongation but can't spot the central star. The distance, always an

/// THE ARCHER

The Archer is wake!
The Swan is flying!
Gold against blue
An Arrow is lying.
There is hunting in heaven—
Sleep safe till tomorrow.
Peace on Earth, *William Carlos Williams (1883 – 1963)*

Sagittarius is one of two centaurs that roam the heavens. The celestial presence of two half-man, half-horse creatures causes some confusion over Sagittarius's identity. While some records state Sagittarius is the wise Chiron, that benevolent centaur is more frequently associated with the constellation Centaurus. (See the April 2003 issue of *Astronomy*.) All accounts agree that Sagittarius holds a bow and arrow, making him appear more representative of the unruly and aggressive centaurs than of gentle Chiron.

The individual originally represented by Sagittarius in Greek mythology was Crotus, son of the goat-god Pan and the Muses' nurse Eupheme. If Sagittarius is the son of Pan, he is more likely to be a satyr — a man-goat — than a centaur. Indeed, Sagittarius is often depicted as having the body of a goat in older records. Crotus was raised among the Muses and became their beloved companion. It was they who asked Zeus to place his image among the stars. — *Vanessa Thomas*

M22 is one of the nearest and brightest globular clusters in the sky, and it can be spotted with the naked eye. JOHN CHUMACK

NGC 6563 is an oval-shaped planetary nebula with a bright outer rim. Astronomers estimate it lies about 2,000 light-years away. JACK MARLING

NGC 6822 was discovered by E.E. Barnard in the 1880s. The dwarf irregular galaxy is a member of the Milky Way's Local Group. CHUCK VAUGHN

uncertain quantity for planetaries, is about 2,000 light-years.

The first of three contrasting globular clusters along the Teapot's bottom, **M69** (**NGC 6637**) lies a mere 4,000 light-years from the galactic center. Dynamical studies show that its orbit is inclined 68° from the galaxy's disk. In a 10-inch, it is 3′ across and reveals 50 stars within a broadly concentrated core. The cluster's perimeter ends abruptly, and an 8th-magnitude star lies just beyond its northwest edge.

M70 (**NGC 6681**) is similar in brightness to M69, but has a more sharply concentrated center. It is located 7,000 light-years directly "below" the Milky Way's center. M70 has some brighter stars than M69, but fewer of them resolve. The cluster's halo extends 5′ in diameter. M70 is often associated with Comet Hale-Bopp. Neither Alan Hale nor Thomas Bopp was actively comet-hunting when they made their discovery in July 1995. They merely pointed telescopes at M70 and spotted a foreign object in the field.

Equally bright as our last two globulars, **M54** (**NGC 6715**) refuses to yield its stars to anything but the largest telescopes. This is explained by its distance of 80,000 light-years. If it were moved to the distance of M22, it would shine at 3rd magnitude. M54 becomes more exotic by its association with the Sagittarius Dwarf Galaxy, which was discovered only in 1994. The tiny galaxy is the Milky Way's closest satellite, and astronomers find it difficult to explain how it has survived intact. Using very high magnification in a 13-inch or larger scope on a night of excellent seeing, you may be able to glimpse a few of its brightest stars, which glow at magnitude 15.2.

Along the border with Corona Borealis, **NGC 6723** is another globular with bright stars in this area. In a 13-inch scope, hundreds of stars brighter than 14th magnitude sparkle across a 12′ diameter. The same low-power field contains a variable reflection nebula, a double star, and a dark nebula.

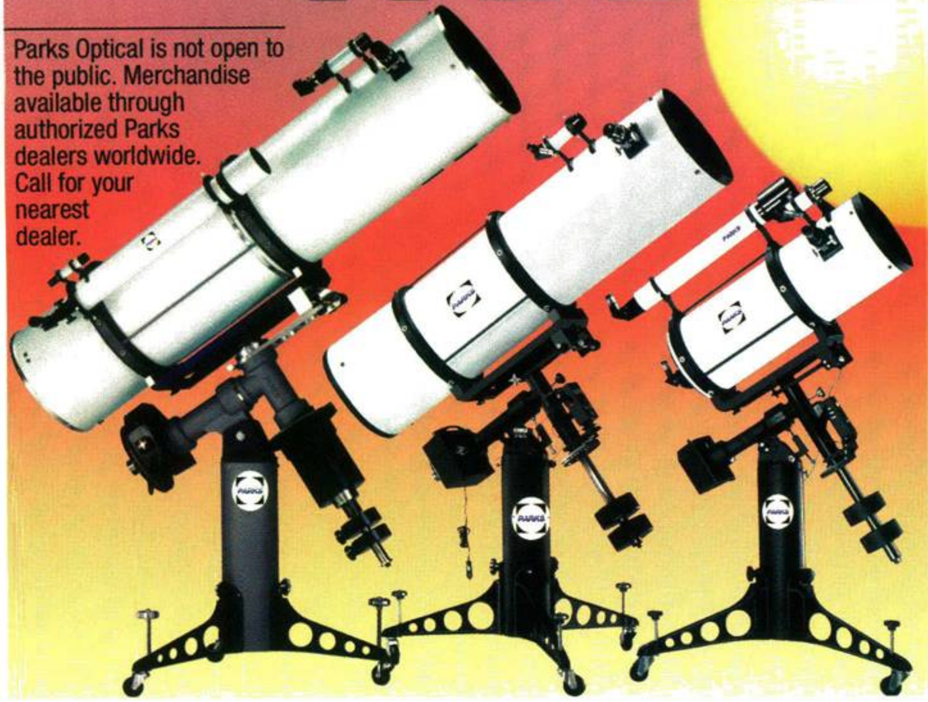
We move well away from the galactic plane to find globular cluster **M55** (**NGC 6809**). While its overall brightness is poor, it is very well resolved into hundreds of 11th and 12th-magnitude stars. At 200x, it looks more like a rich, open cluster than a globular, with no background glow of unresolved stars. Its apparent size is about 10′. An otherwise circular profile ends abruptly at the northern edge.

Our final globular cluster is the distant **M75** (**NGC 6864**). Seen from 60,000 light-years, its brightest members barely show in a 12-inch telescope. It measures 4′ across and has a high degree of central brightening that seems stellar at low magnification but is 30″ across at 300x. The location 25° away from the galactic plane is apparent from the foreground field, which is nearly devoid of stars.

Also situated in the starless fields near the constellation's borders with Capricornus and Aquila is **NGC 6818**, a very bright planetary nebula sometimes referred to as the Little Gem. An Oxygen III filter seems to "overexpose" this highly excited object. The high surface brightness enables the use of elevated magnifications, which show a very sharp-edged disk 40″ across and slightly elongated north-south with a darker center. The central star is too faint to be glimpsed visually. Back off on magnification and view the planetary with direct vision to notice its blue tint.

M55 is about 100 light-years wide, causing it to span nearly two-thirds the area of the Full Moon in our sky. BILL IBURG

While not telescopically spectacular, **NGC 6822** may be the most interesting object in Sagittarius. At a distance of 1.6 million light-years, Barnard's Galaxy is the nearest dwarf irregular in the Local Group beyond the Magellanic Clouds. In 1925, it was the first "nebula" recognized as being outside the Milky Way by studies of Cepheid variable stars. Sweeping across the field with very low magnification reveals a dim haze 10′ by 5′ with a slightly brighter central spine. Dark skies are a prerequisite, and under superb conditions it is visible in a 3-inch scope. Larger telescopes at medium magnification show several HII regions in a string along the galaxy's northern end that are enhanced with a nebula filter. These nebulae are excited by star clusters and rival the most luminous in the Milky Way. Even higher magnification in scopes as small as 12 inches brings out the brightest supergiant stars, which manifest themselves by a granular appearance.



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OBSERVING TECHNIQUES

A fundamental guide to taking dynamic astrophotos. /// BY JOHN SHIBLEY

Simple skyshooting

It may surprise you that the easiest form of astrophotography also offers the greatest variety. Photographic targets through a telescope largely stay the same year after year. But the naked-eye sky changes from day to day, offering an evolving canvas with shifting characters. And all you need is a camera and a tripod to capture it all.

Simple tripod astrophotography requires a manual focus camera that offers variable f-stops. It will need to be able to take pictures with exposure times of a few seconds up to several minutes without drastically draining a battery. If the camera accepts a cable release that manually fires the shutter, all the better. In general, a 35mm camera is ideal; however, a digital camera with the right features will work too (see "Digital tripod photography," page 81).

Depending on what types of objects you'll be shooting, load up with moderately fast (ISO 200 for bright objects) to fast (ISO 400, 800, 1000 for fainter objects) film. Place the camera on a suitable tripod (see "Have tripod, will photograph," below), focus to infinity, and fire away. Vary exposure times for effect.

Read on for ideas and tips that will help you discover all that the sky offers to a tripod skyshooter.

Chart the Moon's motion

The Moon moves 12° relative to the Sun (13° relative to the stars) each day. With just one hour at your camera, you can watch it move its own width across the celestial sphere. Try recording its motion past a bright star or planet, or through a bright pattern of stars with ISO 400 film and a camera lens set to f/2.8 or f/4. Keep your exposures to less than 15 seconds. Use a telephoto lens if the Moon is passing within a few degrees of a marker target. If the Moon isn't passing anything celestial, try marking its motion against terrestrial landmarks. As the Moon's phase grows larger and gets brighter, remove any clear filters threaded to the lens. These create internal glare and ghost images.

Capturing conjunctions

The popular media makes much of "rare" conjunctions. The truth is that interesting groupings between planets, stars, and the Moon happen almost monthly. Some of the most dramatic conjunction photography involves groupings above the horizon before sunrise or after sunset. Use ISO 400 or, if the conjunction involves the Moon and a bright planet, ISO 200 film. Start taking pictures within half an hour after sunset (or before sunrise) with the lens set to f/4 or f/5.6. Vary exposures between 5 and 20 seconds. Consult *Astronomy*'s "The Sky This Month" section for upcoming conjunctions, or pick up reference books such as Guy Ottewell's *Astronomical Calendar* or the Royal Astronomical Society of Canada's *Observer's Guide*. Planetarium and sky simulation computer software like *Voyager* (tailored for Macs) or *Starry Night* also help keep you abreast of conjunctions. Software has the added benefit of almost exactly duplicating your horizon views.

/// HAVE TRIPOD, WILL PHOTOGRAPH

Find yourself a good, beefy photo tripod. Look for one with oversized lock and adjustment knobs that will work well with gloved hands. A good rule of thumb for stability is to measure the tripod legs' tube diameter. The wider the diameter, the greater the stability. Also, make sure the legs expand wide enough for you to move comfortably around the camera in the dark.

Telescoping tripod legs secure with either twist-sleeve or twist-lever locks. Sleeve-lock designs often jostle the tripod when extending a leg. Also, they are prone to over-tightening. This said, having the ability to torque-secure a leg is not necessarily a bad thing. Twist-levers may not lock as securely in colder temperatures. Also, twist-lever locks on cheaper tripods tend to loosen with use and age.

Another good feature to look for in an astrophoto tripod is an adjustable center column. This lets you raise or lower camera height without releasing the tripod's telescoping legs. A useful adjustment feature here is a hand crank that lets you make minor adjustments.

Tripods also come with two types of heads. Ball heads can point in any direction, in one fluid motion, with the release of one lock. A downside to this might be some slight sagging during an exposure if the camera is fitted with a heavier lens. Two-axis heads require a little more dexterity and finesse when pointing, but often lock down securely.

If you plan on hiking to a site, consider a portable tripod that fits into a pocket. Or pick up one with a clamp that attaches to any flat edge, like a board on a fence.

CAMERA AND TRIPOD PHOTOGRAPHY is as basic as it gets. Simply mount a 35mm SLR on the tripod, load it with fast film, and shoot a variety of subjects with ease.

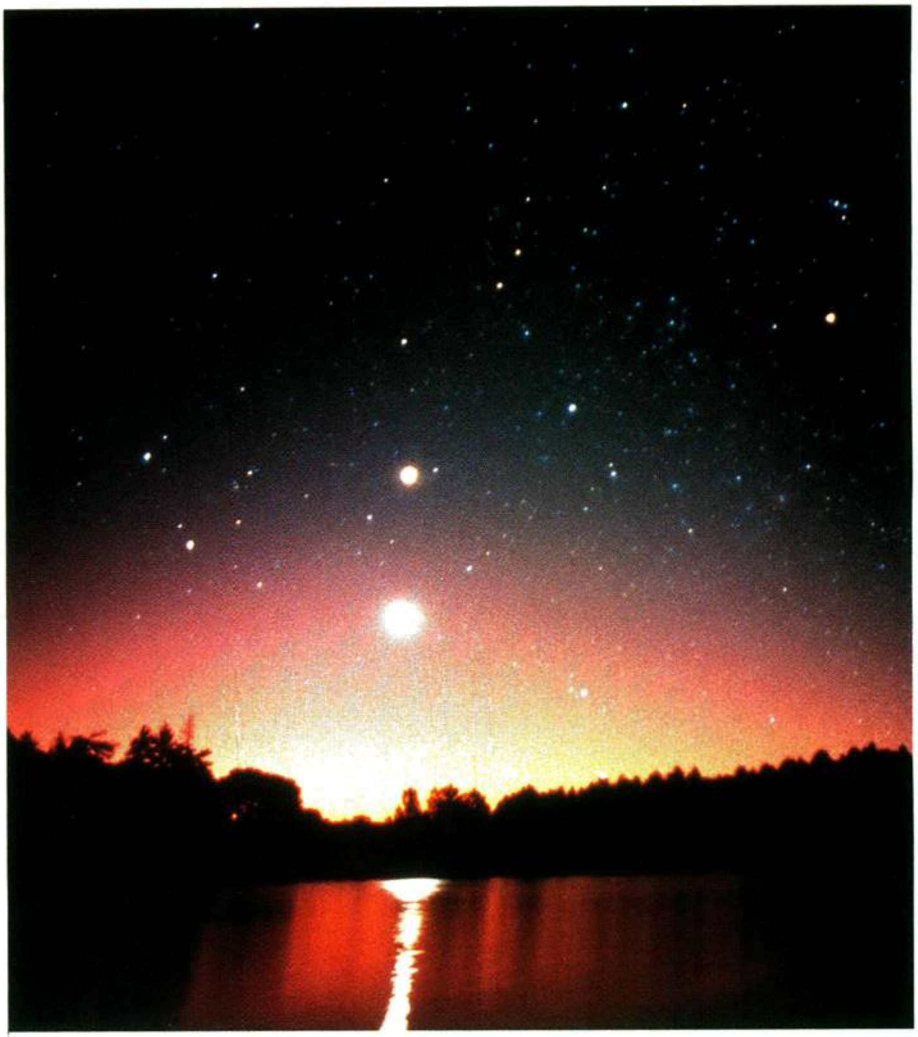
THE MOON AND MERCURY FLOAT over mountains in Southern California in this image shot on June 3, 2000. Ivan Dryer used a 105mm lens at f/2.5 and Kodak Gold VS film for the brief exposure.

Shoot aurorae

Every now and then observers in the mid-latitudes are treated to a show of the aurora borealis. It's best to shoot these dancing lights far away from any man-made sky glow. Keep an eye out to the north for faint rays or fans. A camera loaded with ISO 400 film exposed for up to 30 seconds will catch any faint aurorae. Brighter displays afford you the luxury of using slower, richer-color film, such as ISO 200. If the display is bright and is changing rapidly, you may want to stick to faster film and shorter, 5- to 20-second exposures. In all instances, vary your 50mm (or wider) lens f-stop setting between f/4 and one click in from wide open. Consult the Solar-Terrestrial Dispatch page (www.spacew.com) and Spaceweather.com to stay posted on aurorae activity.

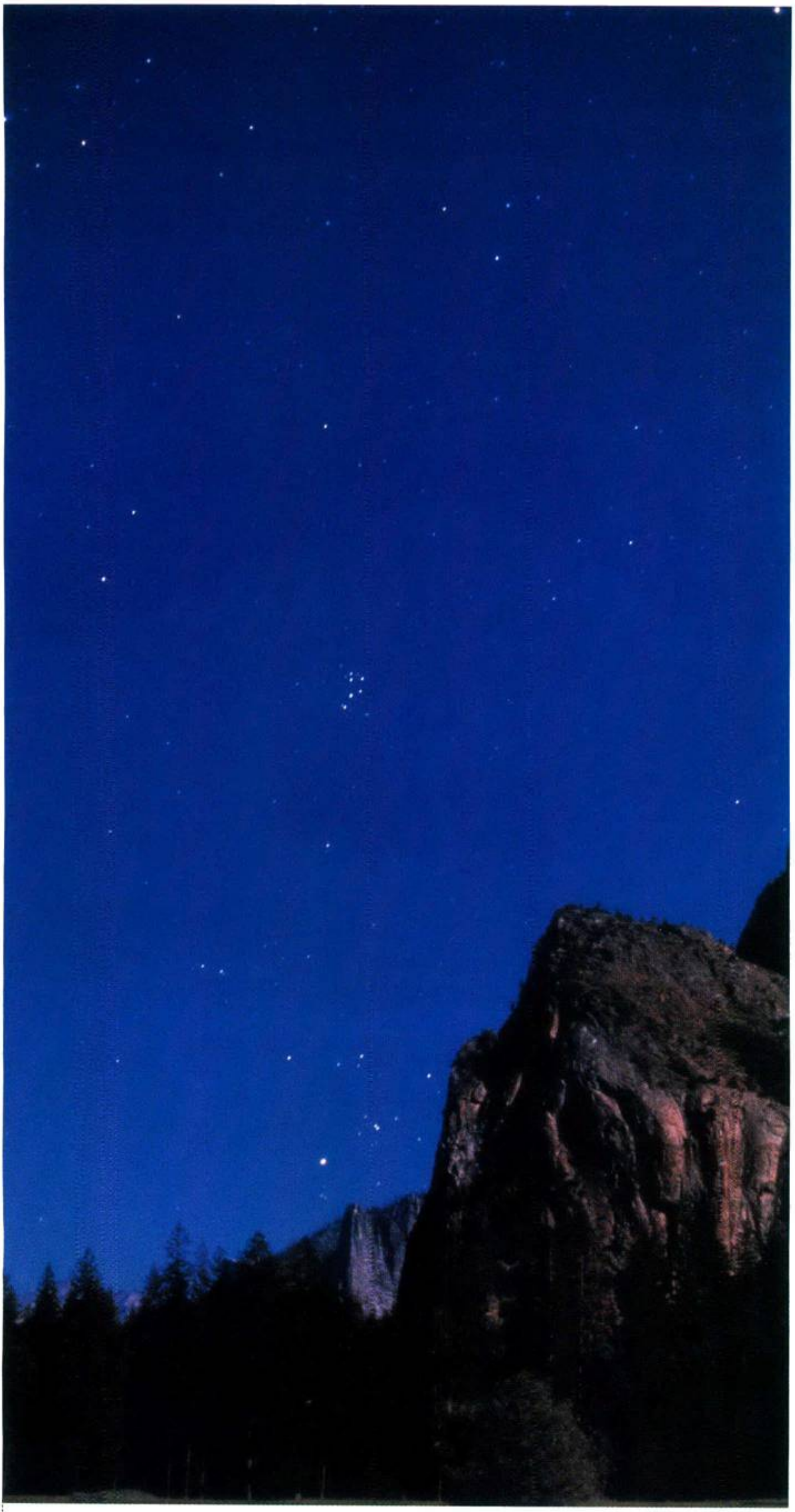
Capture night landscapes

Here's where a moderate amount of light pollution is helpful. Frame constellations or conjunctions with nearby trees or buildings for scale. Don't shoot directly into lights, but place ambient light sources behind you. Shoot a sky target scene with the same settings you'd use to capture any conjunction. If fainter constellations are your target, vary the lens f-stop between wide open and one click in. You may want to take a few 30-second exposures as well. If there's a gibbous or Full Moon, use its light for the same effect. Again, make sure all light shines behind or off to one side to adequately light the terrestrial scene. If there are no ambient or lunar light sources around, provide your own. "Paint" a scene during an exposure with a bright flashlight or even a photoflash.



CUYAMACA LAKE in San Diego County, California, provides a beautiful foreground for this image of a crescent Moon, Venus, and Orion. Jerry Schad used a 24mm lens at f/1.4 for the 45-second exposure on Ektachrome P800/1600 film, pushed to ISO 1600. Schad made the shot on August 15, 1993.

A BLAZING AURORA always makes for a great camera-and-tripod astrophoto. Canadian astroimager Terence Dickinson made this shot with a 28mm lens at f/2 on June 17, 1991.



STARS TRAIL TRUE COLORS across the frame of an image centered on Sagittarius and Scorpius. Tim Barnwell made the 55-minute exposure on July 31, 1997, using a 17mm lens at f/3.5 and Ektachrome 400 film. The bright trail at top left was made by Jupiter.

Catch satellite flyovers

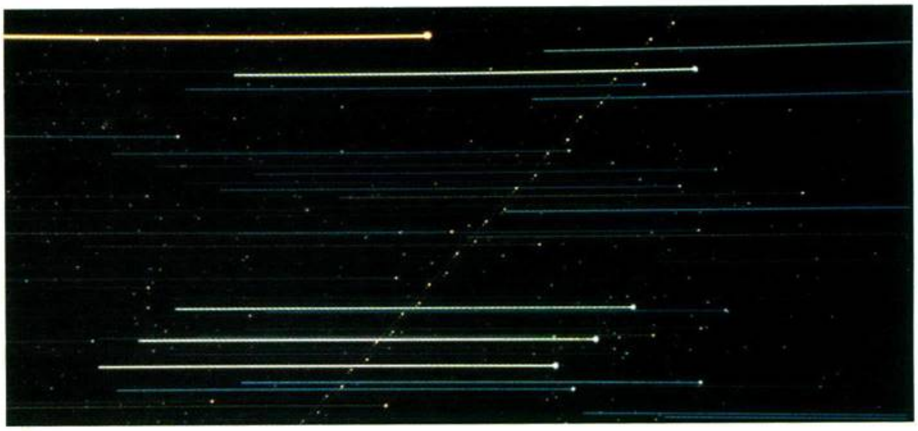
Every night dozens of satellites fly over your backyard. The website Heavens-above.com can churn out prediction times and path charts for most of them. Just log on and type in your site's longitude and latitude. Start photographing brighter flyovers first, such as the International Space Station. A printed path chart can help you plan where to point a camera loaded with ISO 400 film. Get ready several minutes before a pass-by. Aim the camera so that stars along the satellite's path lie along the diagonal of the frame. Set the lens one f-stop click in from wide open. Start the exposure about a minute before the satellite should be visible, and stop the exposure after the satellite passes beyond your field. The satellite will appear as a line crossing a backdrop of star trails.

The Iridium communication satellites can make dramatic targets. They create a momentary "flare" in the sky as they reflect sunlight earthward. Flare times and positions, as well as predicted brightnesses, are also at Heavens-above.com. Use this information to set up your camera as you would for any other bright satellite. You'll record a dramatic streak that starts narrow, fattens, and then narrows again, much like a bolide meteor.

YOSEMITE'S BRIDALVEIL FALLS presents a stellar foreground for this shot of Taurus hanging high in the winter sky. The tiny, dipper-shaped Pleiades star cluster lies left of center, with the V-shaped Hyades just above the mountain. Frank Zullo created this 20-second exposure in early 1995 using a 35mm lens at f/2.0 and Fujichrome Provia 100 film pushed to ISO 400.

John Shibley *plans to practice more tripod astrophotography under the dark skies of Michigan's Upper Peninsula. He also enjoys photographing and observing the Sun when the clouds don't block his view.*

THE STARS OF ORION AND TAURUS float in Jerry Schad's 30-second exposure. He used a 24mm lens at f/1.4 and Ektachrome P800/1600 film at ISO 1600.



STAR COLORS GLIDE ACROSS SPACE in Ron Brown's image of the top half of Orion shot with camera-and-tripod. Brown, of Los Osos, California, used an f/4 lens to take this 60-minute exposure. The strange pair of diagonal dotted lines was created by the wing lights of an airplane that happened to pass through the field of view. Dotted paths can also be created by rotating satellites that rhythmically reflect the Sun.

Record star trails

Center your camera on Polaris for at least a 30-minute exposure. You'll see star trails that arc around the North Celestial Pole as Earth turns. Spice up a polar scene by positioning a tree in a corner. If the night is damp, dew can form on the lens during long exposures. Battle this by attaching a chemical heating pad, such as a glove warmer, to the lens housing. An abstract variation on the star trail theme is to shoot the sky for several minutes through the branches of a tree. Experiment with a telephoto lens to get a distant tree and the sky beyond in the same relative focus.

Capture star colors

Star colors that barely show up to the eye pop out on film. Arcturus, in the constellation Boötes, is a decidedly dusky color, and Antares, in Scorpius, glows red. The Summer Triangle is defined by the blue stars Vega, Deneb, and Altair. To bring a star's color into focus, try taking the star's light out of focus. Position a target star to the east in the field of a 200mm telephoto lens. Using ISO 400 film and a wide-open aperture, start a several minute exposure. Because this is a long exposure, set up away from urban lights on a moonless night. During the exposure, twist the lens's focus incrementally inward ever so slightly every ten seconds or so. The resulting photo will capture the star "fanning" out of focus. Star colors become more noticeable as the image fattens.

Snare ocean light reflections

Fit a telephoto lens to a camera loaded with ISO 200 or 400 film. Shoot the crescent Moon as it draws near a foreground tree or tree line. With the lens set to f/5.6 or f/8, take exposures of between 5 and 20 seconds. What you'll get is an overexposed sunlit portion of the Moon, with earthshine forming a complete disk. Expect the earthshine to look bluish; this is light reflecting off Earth's blue oceans and atmosphere onto areas of the Moon still in darkness.

Record constellations

Create your own naked-eye star atlas by recording a collection of constellations. Use ISO 400 film for exposures of between 20 and 30 seconds. Vary the camera's f-stop between wide open and one click in from wide open. A 50mm or 35mm lens works well to capture most constellations. Shoot from a site that's removed from city lights to avoid sky glow. Otherwise, use a soft man-made glow to illuminate a foreground scene to add scale to your photos.

The beauty of tripod astrophotography is not only simplicity but also its free-form nature. By all means, this list of targets and projects is not the limit of what you can do. Anything in or near the sky is fair game. Shoot stars over a lake. Capture a conjunction scene from the top of a building with streets streaked in car taillights. Aim toward a meteor shower radiant while recording star trails. Try double exposures with the Moon or shoot a sequence with a bright planet.

When it comes to simple tripod astrophotography, the sky is — quite literally — the limit.

/// DIGITAL TRIPOD PHOTOGRAPHY

Not all digital cameras have the right stuff for tripod astrophotography. But many of them offer sensitivity options analogous to ISO 400 or faster film. Here are a few essentials to look for:

Manual focus. Be able to manually set the camera's focus on infinity for faint constellation photography. In some cases, the camera's autofocus will work with the Moon in its field of view. Even then, make sure the camera doesn't lock focus on a foreground building or tree line.

Manual aperture/shutter speed controls. The sky is a dark place. Consequently, your camera may be fooled into taking a paltry flash photo. You must be able to manually select several-second exposures with the lens set as wide open (if the camera even varies its aperture) as possible. Overriding the flash is also a necessity; you may not want to ruin your night adaptation or light up hazy night air.

Dark-frame subtraction. The sensor chip in a digital camera creates a "noisier" picture the longer it is exposed, full of snow and spurious-colored pixels. The image often degrades during a one-second exposure. Some digital cameras will automatically shoot a "dark frame" after you take the time exposure. Software in the camera uses this noisy frame to subtract almost-identical noise from the real frame.

As with most things in life, options cost money. More expensive models offer the flexibility that's required to grab small-time exposures of the sky.

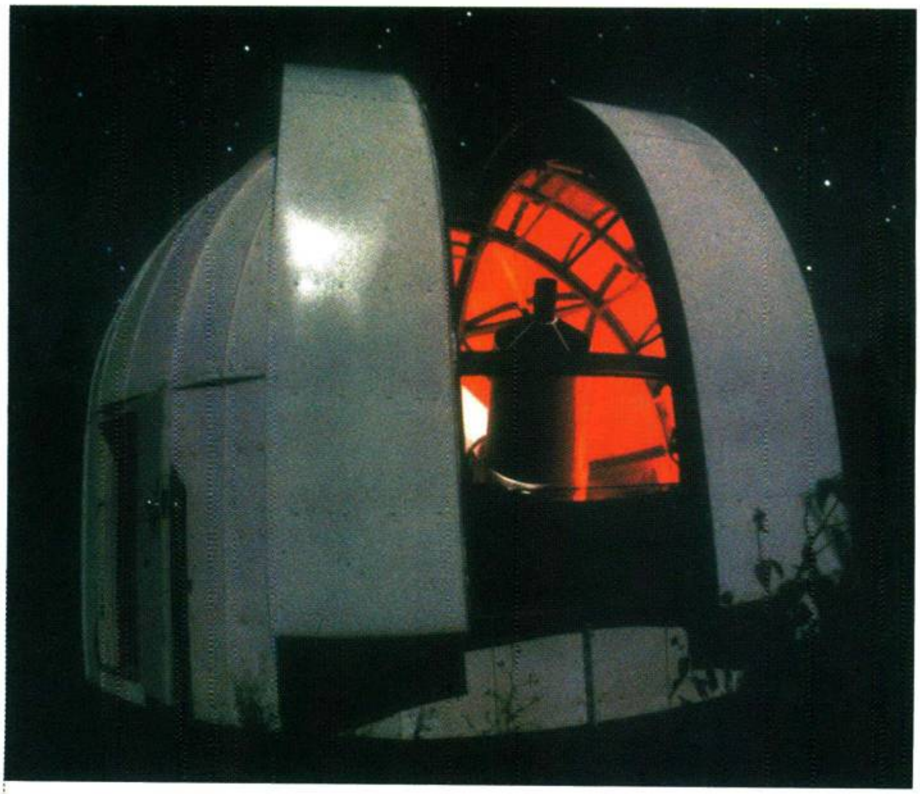
For more about depth in observing, visit http://www.astronomy.com/toc.

A great vacation spot awaits amateur astronomers. /// TEXT AND PHOTOS BY TOM POLAKIS

A visit to Star Hill Inn

Rather than grumbling about the dome of light pollution and pall of clouds overhead, many folks with an astronomical interest prefer to travel to dark-sky sites situated in the Southwestern United States. Not long ago, executing this sort of vacation was a Herculean task. The search for a suitable observing site was not easy. The site needed to be away from lights and traffic, which translates to a hostile place with no services, offering only the most primitive lodging. Next, amateurs had to lug small telescopes that filled one or two suitcases through airports, subjecting them to baggage handlers. All that changed in 1988, when Star Hill Inn, the country's first guest observatory, opened in northern New Mexico. Since then, many similar observatories have followed the Star Hill Inn model, signaling a change in the way amateurs vacation.

A trip to Star Hill Inn typically begins with a flight to Albuquerque. A two-hour drive brings you to Las Vegas, New Mexico, a town of 15,000 some 20 minutes south of the observatory. Among the town's appreciated amenities are grocery stores and restaurants. You don't want to miss the New Mexican cuisine at Johnny's Mexican Kitchen. The Department of Tourism calls northeast New Mexico the place "where the Great Plains meet the Rocky Mountains," and nowhere is that more evident than on the drive out of Las Vegas to Star Hill Inn. On the right as you drive, ranches and farms dominate the landscape to a seemingly infinite horizon that stretches toward Texas. To the left, foothills give way to peaks rising higher than 12,000 feet in the Sangre de Cristo Mountains.



STARS SET over the dome of the 24-inch Ritchey-Chrétien telescope as it peers toward the east. The large aperture of this scope makes it one of the prime attractions at Star Hill Inn.

Just shy of the tiny village of Sapello, a welcome left turn leads to a short rise into a pleasant Ponderosa pine forest. Star Hill Inn is located in the foothills of the tall mountains at an elevation of 7,200 feet, which is in the "optimal" range for visual astronomy. At a wide spot in the road, a dome and an observing deck appear, marking the isolated acreage of Star Hill Inn. Even in daylight, it is clear this is a superb astronomical site.

The origin of Star Hill Inn

Phil Mahon did not have a life plan to create a guest observatory. In 1982, he moved from Dallas to northern New Mexico for its dark skies. There he was employed at a title insurance company doing title searches and escrow closings. During that period, he made several trips to Ghost Ranch in Abiquiu, New Mexico, where he assisted in teaching an astronomy class. One day he looked at his Mount Palomar T-shirt in the mirror, bemoaning the fact that even this observatory is no longer a dark site. He says the shirt provided him the emotional inspiration (and his teaching provided the practical experi-

IN THE LIBRARY, Texas amateur astronomer Danny May prepares for a long evening of observing by creating a detailed personal target list.

ence) to offer a place where anyone could comfortably enjoy the night sky.

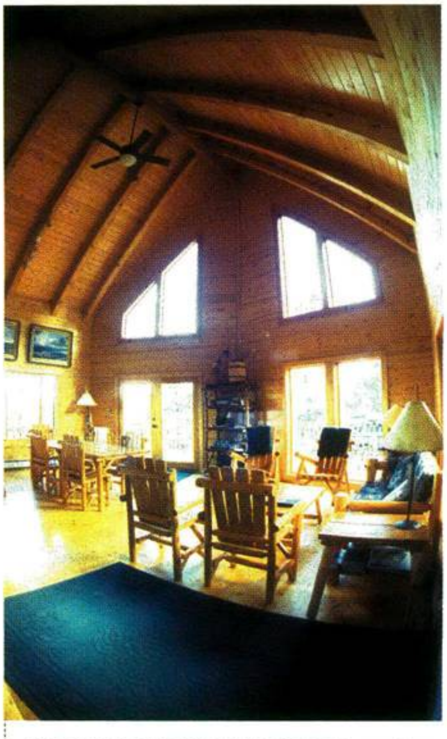
So with the purchase of 200 acres, Mahon opened his observatory in 1988 with two guest houses and access to three telescopes: a Coulter 13-inch Dobsonian and two Meade Schmidt-Cassegrains (SCTs). Star Hill Inn was born. It wasn't long before calls came in from those who said they had similar ideas but hadn't followed through on them.

Mahon has an unlikely combination of degrees in mathematics and theology, which he notes are oddly appropriate for his current occupation. Like so many amateur astronomers, he is "evangelical" about teaching astronomy. Instructing newcomers is his greatest joy, and it's what keeps the observatory healthy and growing. Half of his visitors are not hobbyists; rather, they are newcomers with a desire to learn. Often, they fumble a bit on that first night trying to locate M13, only to return a year later as full-fledged amateur astronomers. Mahon gives them a one-hour "star tour," in which they are taught the basics of reading charts and pointing telescopes.

Mahon recalls his favorite star tour. In 1990, Rae Ann Kumelos (pronounced like the fair-weather cloud) read a travel magazine story about Star Hill Inn and filed it away. Seven years later, after rereading it, she made the trip from her home in northern California, and the two quickly realized their lives were about to change. They married at Ghost Ranch less than a year later.

What comes with your visit

The use of one telescope is provided in the rate for each house. Current instruments range from a 7-inch refractor to a 22-inch Dobsonian. If you don't know which scope suits you, Mahon does a "profile" to set you up. Shelters on the deck roll completely off the telescopes they cover, leaving observers open to the night air. In addition to the scopes on the deck are empty piers ready for mounting



THE SUNRISE HOUSE LIVING ROOM is comfortable and spacious.

/// STAYING AT STAR HILL INN

Travel

Star Hill Inn is a 2½-hour drive on good roads from Albuquerque, New Mexico, whose airport is served by the major airlines. You will want to make a stop in Las Vegas, NM, along the way for groceries and other supplies. Specialty grocery stores can be found in nearby Santa Fe.

STELLER'S HOUSE is a great place to relax after a long night under the stars.

Lodging

Each guest house has a full kitchen and utensils. The minimum stay is two nights. Economical lodging can be found in the one-room Cosmos, which has a queen bed and runs $155 per night. Steller's has two bedrooms and sleeps five for $220 nightly. Large groups may consider staying at Sunrise House for $375 per night.

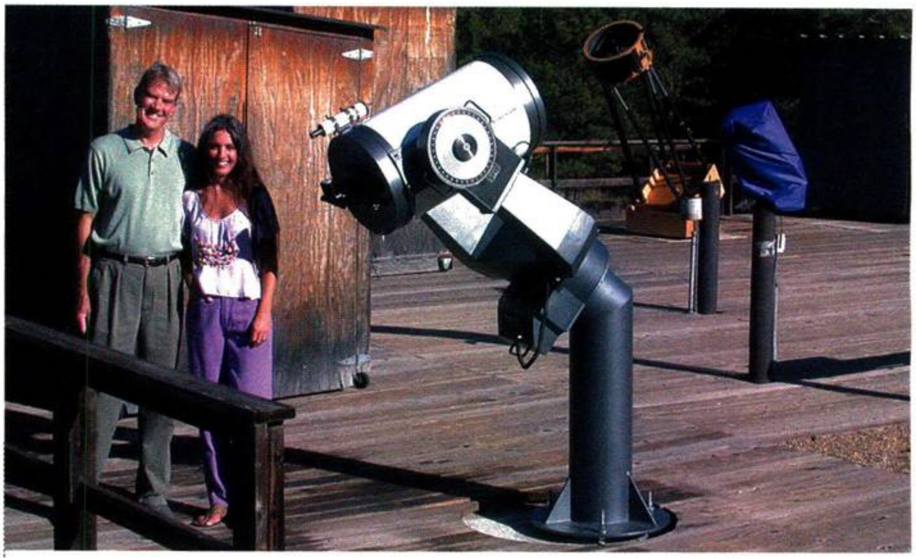
THE SUNRISE HOUSE offers Star Hill Inn's most luxurious accommodations.

Observing

Phil Mahon provides a one-hour star tour each clear night. One telescope is provided per guest house. Large Newtonians include a 17½-inch Sky Designs and a 22-inch Starsplitter Dobsonian. The 16-inch and 12-inch Meade LX-200s and the 14-inch Celestron Compustar Schmidt-Cassegrain telescopes have electronic pointing. A 7-inch Meade refractor also finds targets unassisted.

More information

Find Star Hill Inn's website at http://www.starhillinn.com. Be sure to take a look at their new forums.



OWNERS PHIL AND RAE ANN MAHON pose next to the 16-inch LX-200 scope on the observing deck. The two met in 1997 when Rae Ann visited Star Hill Inn. They've been together ever since.

popular Meade and Celestron SCTs. Many visitors to Star Hill prefer to bring their own familiar scopes.

In addition to the constant upgrading of astronomical equipment, lodging at Star Hill Inn continues to be a work in progress. Since its humble beginning, the inn has added six new dwellings ranging from the economical Cosmos House to the palatial Sunrise House, perched scenically on a hillside. All come equipped with full kitchens and spacious living rooms. Windows are well-covered so light does not leak out at night or in to wake guests during late morning sleep-ins. The houses stand well away from the observing area, deep in the forest. The only sounds you hear during the morning hours come from the local fauna.

From the deck of the Sunrise House overlooking the expansive plains to the east, Phil described the instruments. While the 22-inch Starsplitter Dob is the largest, it is not the most popular. The favorites are those with microprocessor control and databases of astronomical objects, such as the 14-inch Celestron Compustar, whose computer contains 8,000 objects and requires no knowledge of the sky to point. Likewise, the recently added Meade 12-inch and 16-inch LX-200 scopes go to their objects unassisted. Keeping up with the times, two SBIG products have been added to the arsenal: an ST-7 CCD camera and STV digital video camera. Of course, aperture fever has no bounds. Mahon looks forward to the delivery of a 30-inch Obsession this year, which will be the company's last delivery of that model.

Only one telescope requires additional payment, and justifiably so. In a dome across the road is a 24-inch Ritchey-Chrétien. The impressive professional instrument occupied a spot on Colorado's Mt. Evans until 1996, when it was replaced with a 28½-inch binocular telescope. At more than 14,000 feet, Mt. Evans remains the site of the country's highest-altitude astronomical observatory. Mahon thinks of the stories the scope could tell about its experiences in that hostile environment. Now, comfortably tucked away in a forest at half the altitude, he adds, "it thinks it's on the beach." Transporting the dome and 10,000-pound assembly to Star Hill Inn was no mean feat. For those who want to experience a professional-grade telescope, it is worth the extra hundred bucks a night that it commands.

The Star Hill Inn experience

I have lived in the Southwest long enough to know that, even at the best sites in the continental United States, at least one in two nights is cloudy. If you want to do better, start planning for more rustic accommodations in the Atacama desert in Chile. In the desert Southwest, July and August are notorious for impressive thunderstorms, as the infamous summer "monsoon" sends moisture from the

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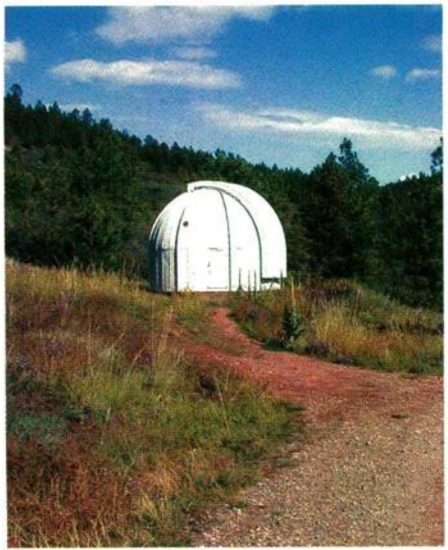
Tom Polakis *lives in Tempe, Arizona, and enjoys deep-sky observing and astrophotography.*



THE 24-INCH RITCHEY-CHRÉTIEN TELESCOPE, safe in its dome, waits patiently for the night.

THE OBSERVING DECK is the main activity center of Star Hill Inn. Shelters that protect the telescopes during the day are removed at night. Also, piers are provided for visitors who bring their own scopes.

Gulf of Mexico. Fortunately, Star Hill Inn's location in northern New Mexico is farther from the source of these storms than more southerly locations. In addition, winter storms can bring blustery conditions and significant snow to high elevations such as these. It's advisable to book a stay at Star Hill Inn for multiple nights, and plan other activities for those days when you've had too much sleep on the prior night.

My two-night stay at Star Hill Inn went about as expected. I was not surprised when the early-October Friday night began with clouds that thickened and finally produced rain. We tried the time-honored tricks of taking naps and covering the scopes, but the overcast wouldn't relent. Unlike observing at a remote site, all is not lost when weather happens at Star Hill Inn. A library adjacent to the observing deck provides comfortable shelter. A video collection next to the television set includes all the favorites from *Star Wars* to *Contact*. The same goes for the stock of magazines and books. We settled in with cookies and coffee and exchanged astronomical stories.

After a sleep-filled night, I arose determined to take advantage of local attractions. Early risers can make the 1½-hour drive to nearby Santa Fe and Taos. Also within reach are Chaco Culture National Historical Park and Bandelier National Monument. The more ambitious can reach the VLA radio telescope in Socorro with a five-hour drive. I'm a hiker, so I headed to the Three Sisters wilderness area for a long climb through alpine terrain.

Saturday afternoon cleared, and the deep blue sky unique to high elevations promised a good night. In the evening twilight, Bob and Judy Vineyard from Colorado Springs were on the deck assembling their own scopes on the permanent piers. Repeat visitors such as the Vineyards are common at Star Hill Inn. This was Bob's sixth trip, and Judy's third. They brought R2D2 and Oester, their 10-inch Meade GPS LX-200 and 8-inch LX-3. When asked why they would travel so far with their own scopes, Bob points to the services, which include a warm lodge and a great astronomical setting. And the nearby attractions of northern New Mexico make for a nice change of scenery as well.

In contrast to the Vineyards, three hardy amateurs rented the big 24-inch across the street. Danny May made the trip to this part of New Mexico from northwest Texas with his friends Jeremy Combs and Larry Parker. The three have backpacked annually in the Sangre de Cristo Mountains for longer than he can remember. Danny says he has come to this part of New Mexico since he was two years old. But this was their first Star Hill Inn visit, and they were going to do it in style.

After some brief instruction, they were dialing in deep-sky objects like pros and enjoying personal best views each time. This clear night showed just how much a dark site in the Southwest is capable of routinely delivering. I pointed out the planet Uranus, which each of them saw very easily without optical aid. Near the zenith, the Milky Way from Cygnus through Cassiopeia glistened with star clouds. To the south, the Las Vegas sky glow was surprisingly dim, considering all those lights are a mere 10 miles away. This has a negligible effect on observing, and no other light domes are visible. Through the 24-inch, the globular cluster M13 was a fully resolved sphere of stars, holding up to high magnification well. The open cluster NGC 7789 showed off its dark lanes interspersed with bright star patterns. The three observers were not impeded by moonlight and continued well into the morning hours without supervision.

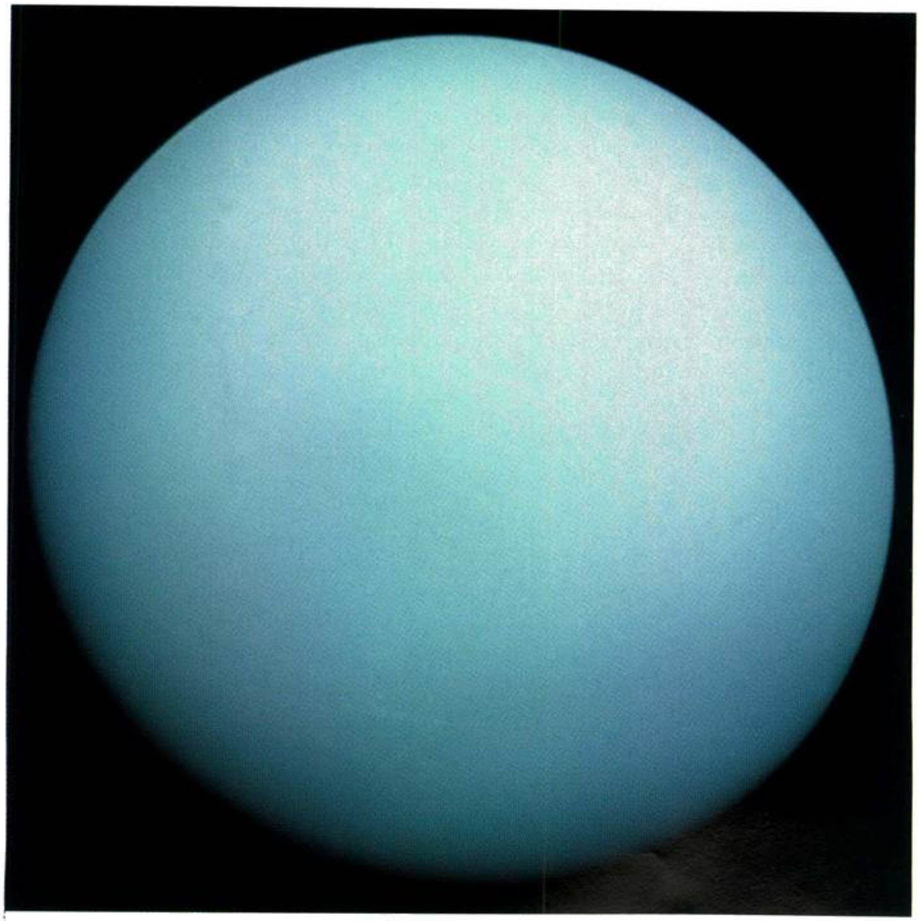
That Saturday night's scene was likely repeated at other guest observatories throughout the Southwest. At last count, there were a half dozen such places in Arizona and New Mexico, and demand continues to increase as more people discover the pleasure of astronomy vacations. Mahon is pleased with what he started, pointing out that Mike and Lynn Rice, who own New Mexico Skies to his south, stayed at Star Hill in 1997. Many choices are now available to avoid the hassles of remote observing. After 15 years in the business operating at an excellent astronomical location, Star Hill Inn remains a prime destination for traveling astronomers.

To learn more about the Star Hill Inn, visit http://www.astronomy.com/toc

Spotting Uranus and Neptune is easier than you may think. /// BY ALISTER LING

Gunning for the gas giants

For the amateur astronomer, Uranus and Neptune are all about wonder and inspiration. Both are magnificent worlds brought to life by the Voyager spacecraft. Under a starry sky, however, it's not about what you see — the tiny disks; it's what they are — swirling, cloud-covered planets a mind-boggling 1.8 billion and 2.7 billion miles out in space. All it took to discover Uranus was the sharp eye of Sir William Herschel, who found it in 1781 in a 6-inch home-built Newtonian telescope. Herschel noticed it because the planet had an unusual greenish hue and its light seemed flatter compared to the sharper stars. He also detected a very slow motion.



URANUS SHOWS FEW FEATURES when viewed through earthbound telescopes. This 1986 Voyager 2 image was disappointing to scientists because of the lack of detail. NASA

From a dark country sky, Uranus is within range of your unaided eye. Distant Neptune offers a bit more of a challenge to the true beginner, but with the provided star charts and a bit of determination you can track down both planets in binoculars.

Timing is the key. Avoid the nights from the 11th to the 15th, when the Moon throws its full glare in the neighborhood. Be watchful of the hour. With Uranus and Neptune lying low in the sky for Northern Hemisphere observers, wait until midnight before making an attempt to locate them. The charts here cover the positions of both planets through September. In autumn, the pair is well-positioned after dark. If you can see only a handful of stars through a bright humid sky, give yourself more time, or wait for a better night.

Uranus

Uranus is a snap to find, floating one to two binocular fields to the upper right of brilliant Mars. On your first try, don't worry if you need 30 minutes to be sure you've sifted Uranus from the background stars. By your third or fourth night of observing, it might take you only 10 seconds to find its greenish glow. That's the way starhopping often works.

Although Mars itself moves from night to night, it is a great point of reference. Using binoculars, start to the upper right of the Red Planet and latch onto a crooked Y-pattern of stars. Some of those stars are fainter than our target, some are brighter. If you are relatively new at using binoculars, prop your elbows on the hood of a car or on a table to steady yourself. In a telescope, don't expect to see the tiny disk of Uranus at magnifications below 100x.

Alister Ling is a meteorologist with Environment Canada who enjoys observing the outer planets.

VOYAGER 2 CAPTURED NEPTUNE and its Great Dark Spot as it flew by in 1989. Due to Neptune's tremendous distance, the only feature seen here visible in amateur scopes is its bluish color. NASA

Neptune

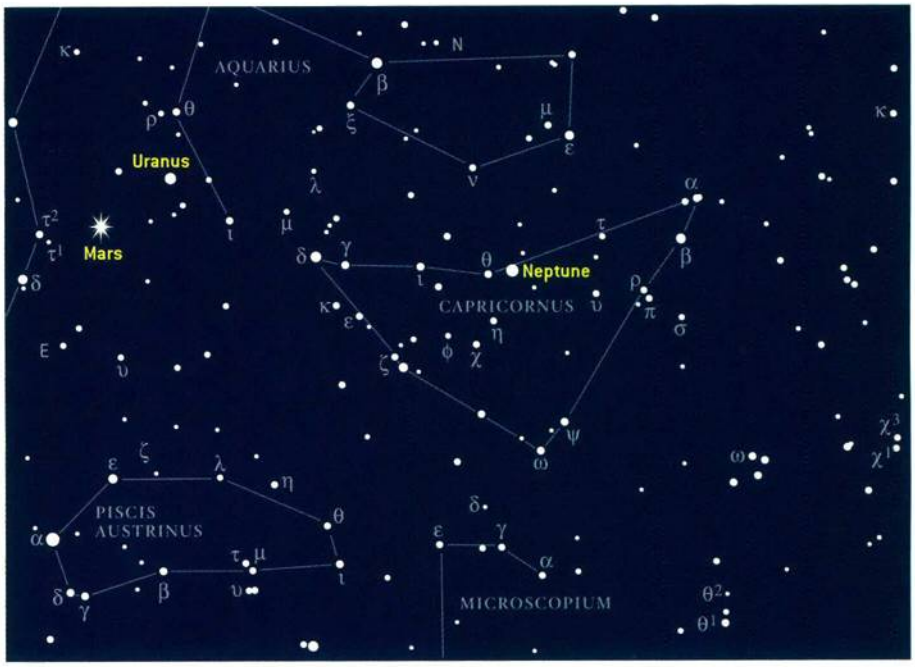
Finding Neptune for the first time is worth a quiet celebration. It's normal to take 30 minutes or more, so don't get discouraged. Even if you have an accurate go-to computer-driven mount, you still have to confirm which "star" is the planet. Neptune's enormous distance of 2.7 billion miles reduces its apparent size to a dot barely bigger than a star in the field of view. And don't just assume it's the one closest to the center of the field.

First, use binoculars to find the neighborhood and identify the stars Theta (θ) and 19 Capricorni. Then begin your telescopic search. Are you upside down or reversed? Find instructions and maps at Astronomy.com. You'll need a reversed chart if you're using a star diagonal.

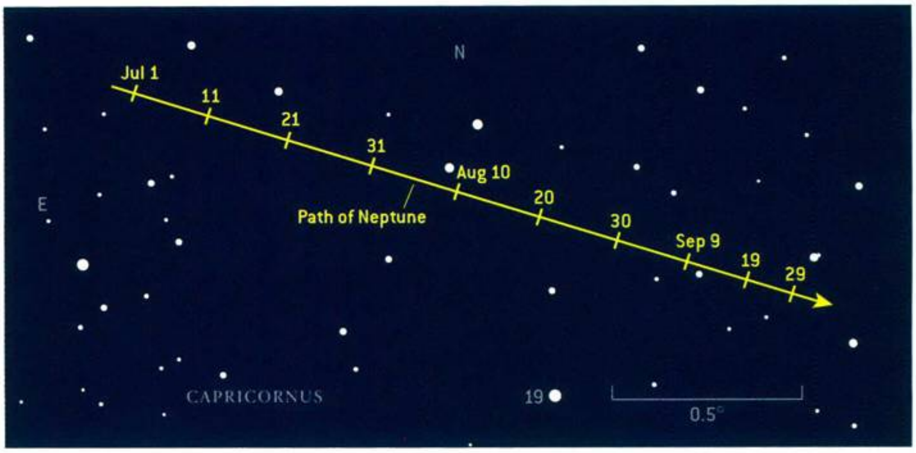
For all other telescopes and finders, turn the page upside down to create an inverted chart. Use a faint red flashlight to illuminate the map, and start with your lowest power eyepiece. Compare the size of the Moon in this eyepiece to the marker on the chart. Slowly slew your scope from one star in the chain to another, making sure the angles and gaps match the ones on the chart. At low power, Neptune's extremely tiny disk may be indistinguishable from a star.

Short-cutting usually leads to frustration, so take it easy. After a handful of Neptune encounters, you'll be able to scoop it up in a couple of minutes. **A**

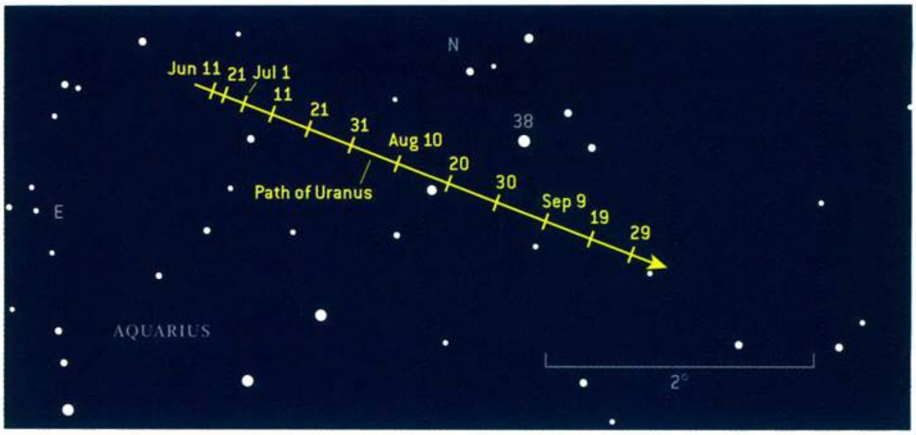
For more about depth in observing, visit http://www.astronomy.com/toc.



URANUS LIES TO THE UPPER RIGHT of brilliant Mars this month, while Neptune is in the middle of Capricornus. Use binoculars and this chart to locate the field for each planet.



NEPTUNE MAY BE FOUND using a telescope and this chart, which shows a smaller area and fainter stars than the Uranus chart. Use the size of the Moon to make sense of the distances in the eyepiece. [The scale gives the Full Moon's width, which is 0.5°.] Neptune will be brighter than the faintest stars shown here. Remember to invert or reverse the map as explained in the text.



THE PATH OF URANUS over the next few months takes it through the Y-shaped group of stars mentioned in the text. From a dark sky, binoculars will easily show all the stars on this chart, and in this orientation.

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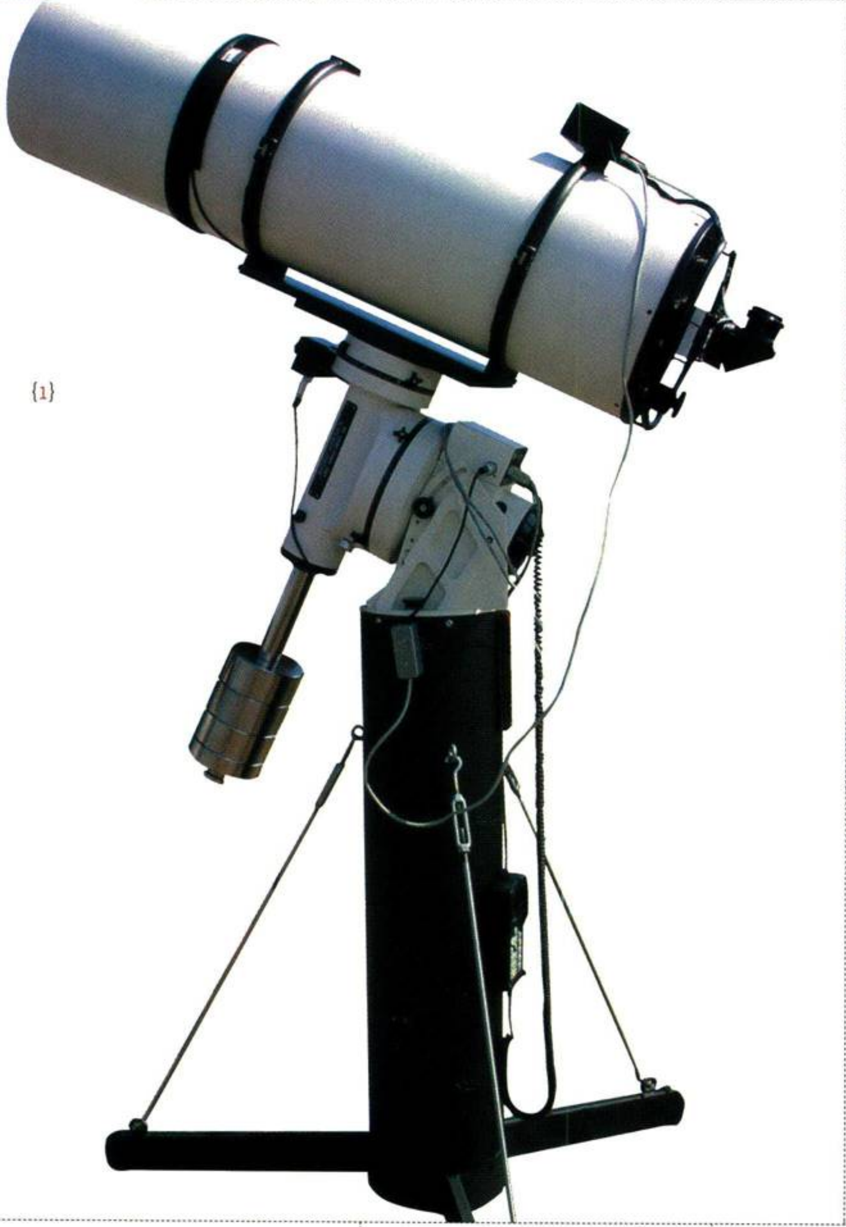

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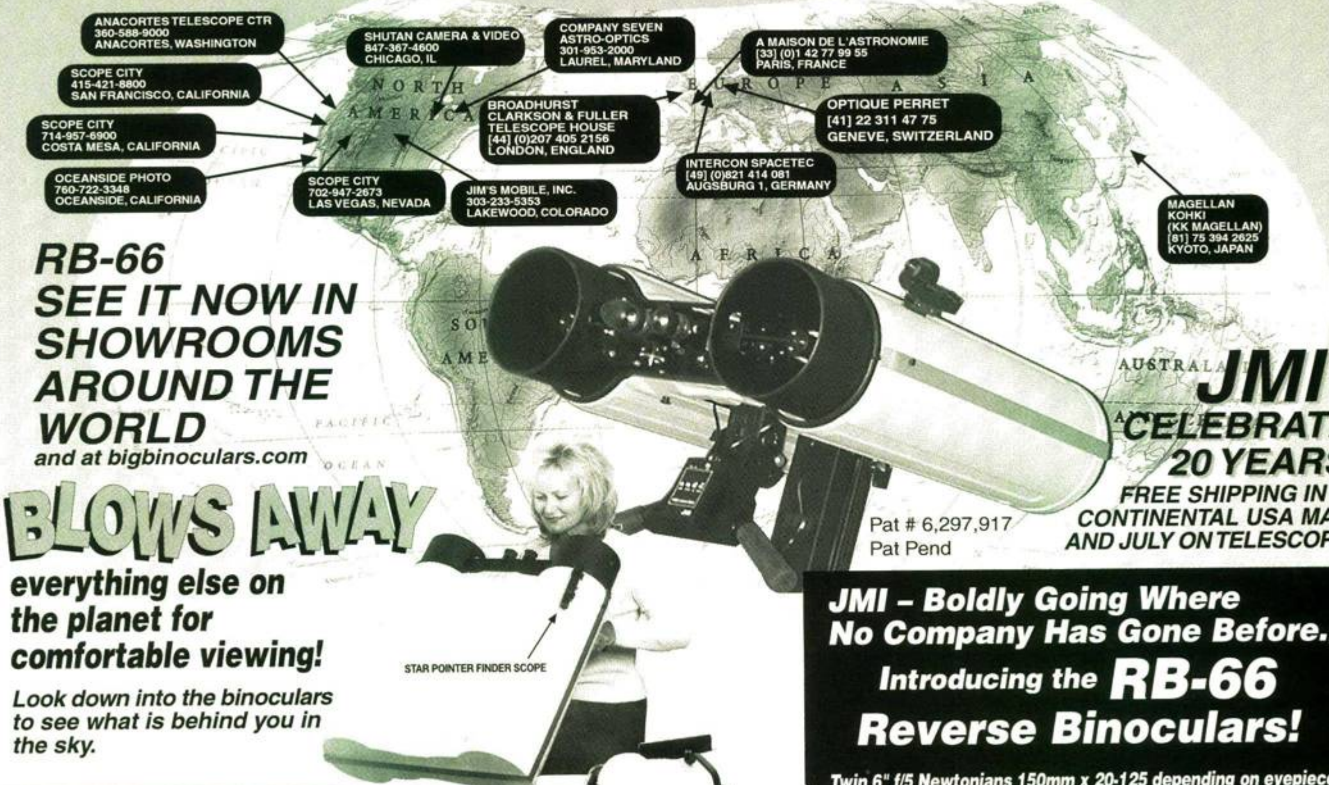

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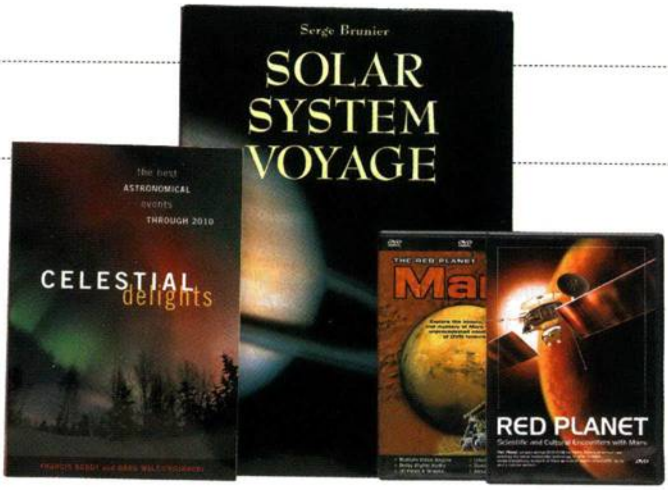


Celestial Delights

Francis Reddy and Greg Walz-Chojnacki, 268 pages, Celestial Arts, Berkeley, California, 2002; ISBN 1-5876-1157-0; paperback, $19.95.

Celestial Delights is one of those titles that could mean just about anything, but the subtitle sets you straight: "the best astronomical events through 2010."

The book, aimed mostly at observers in mid-northern latitudes, focuses almost entirely on what you can see with your eyes alone, with some binocular use. It is organized in chapters that focus on one or two easy targets: the five naked-eye planets (Mercury through Saturn), solar and lunar eclipses, meteors, aurorae, comets, and the major constellations.

The chapter on Venus typifies the approach. The authors describe the planet's role in various mythologies, its brightness, its physical state as revealed by space probes, and its apparitions in the morning and evening sky through March 2011. Simple black-and-white horizon diagrams trace its trajectory.

Illustrations are clear and mostly black and white, except for an eight-page color section in the middle. The few black-and-white photos all look pretty murky. Five appendices provide a year-by-year recap of all celestial events, lunar phases, oppositions, greatest elongations, and additional Internet resources.

The book's long span of coverage not only keeps it current for many years but also helps illuminate the physics behind what we see — for example, Venus's motion relative to our own planet's and to the Sun.

In an age when planetarium software can show you the sky at any time, from any location, is there a need for books like this? Two reasons explain why the answer is yes. First, sky-viewing software, even well-designed programs such as *Starry Night*, can often leave beginners baffled for lack of astronomical context. The authors here provide a pleasant and enjoyable tour that will keep beginners oriented. Second, a book that takes a long look into the immediate future lays out the astronomical events that are worth planning for. I'll be keeping my copy close at hand. — **ROBERT BURNHAM** *is a contributing editor of* Astronomy.

Solar System Voyage

Serge Brunier, 248 pages, Cambridge University Press, New York, 2002; ISBN 0-5218-0724-7; hardcover, $40.

A note on the back of Serge Brunier's coffee-table book *Solar System Voyage* proclaims it to be the winner of a 1997 "Astronomical Book of the Year" award in France. The competitive field must have been thin that year, as this poorly written book is dated and riddled with errors.

The book is an informal tour of the solar system with stops at all the planets, plus a few comets and asteroids along the way. The text is romantic and evocative, detailing what it would be like to visit many planetary systems — I found a section on traipsing through Venus's oddly thick atmosphere particularly compelling.

As interesting as parts of it are, however, more entertaining is spotting the factual errors that pockmark nearly every page. Water's "triple point," the temperature and pressure at which the molecule can exist in equilibrium as a solid, liquid, or gas, is said to occur at a pressure of 1,000 millibars (about the atmospheric pressure at sea level) — in truth, it's 0.005 this amount. The difference could be overlooked if the narrative did not then use the wrong figure to justify several incorrect "facts" about water on Mars. Elsewhere, the rate of asteroid detection is said to be "tens" per year when it's actually *tens of thousands*. The asteroid Gaspra is said to have "less than 100 craters," yet a glance at the photo on the facing page shows almost double this number (and published crater counts are about ten times as high). This is almost certainly the first book in the history of astronomy that calls Comet Halley a planet but a few pages later denies that same title to Pluto.

When it is not flat-out wrong, the language is overly grandiose and vague. Does our galaxy really spin "infinitely slowly" and contain an "almost infinite" multitude of stars, many with an "almost infinite" life expectancy? In a poetic sense, of course it does. But in the context of understanding the solar system, such artistic license often renders the text meaningless.

To top it off, the book is somewhat dated. The Mars chapter relies heavily on Viking data. They're beautiful images, but Mars Global Surveyor has been in orbit for more than five years now, and none of its images are included. Neither will you learn much about its findings — of purported ancient lakes and recent liquid-water-formed gulleys on the Red Planet. Similarly, the best images of the Jupiter system are from the Voyager flybys more than 20 years ago — there's almost nothing from Galileo and Cassini. The Magellan Venus maps are marked as "preliminary" — from the early 1990s. No text can remain completely current, but the last six years have seen the most active exploration of our solar system ever. Why publish a book that is so far behind from the start?

The field of solar system books is replete with other fine contenders (e.g., Fredric Taylor's *The Cambridge Photographic Guide to the Planets* or Ronald Greeley's *The NASA Atlas of the Solar System*). Leave this one alone.
— **HENRY THROOP** *voyages through space vicariously using the Cassini spacecraft.*

Mars: The Red Planet

AlphaDVD; www.MarsDVD.com; $19.99; minimum requirements: standard DVD player or Windows 95.

Red Planet: Scientific and Cultural Encounters with Mars

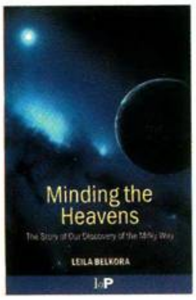
University of Pennsylvania Press; www.mariner10.com; $39.95; minimum requirements: Windows 95 or G3/iMac.

With two multimedia DVD programs, viewers can explore Mars of the past, present, and future from their own homes.

Mars: The Red Planet is a benchmark for this kind of technology, filled as it is with multi-angle video, multi-track audio, video and still images in 3-D (glasses included), an art gallery, subtitles, and captions. The opening menu offers a choice between interactive or entertainment modes. With the latter, you can sit back and enjoy the entire DVD sequentially over 90 minutes. The interactive mode, however, is where this resource truly shines. Zoom and pan over the alien terrain of a martian map; get the feeling of blasting into orbit with video shot from a Delta rocket; flip through extensive chapters of text, graphics, and audio from decades of Mars missions; and find hidden, bonus video sequences from specific flights. This is a must-have for anyone interested in a personal, guided tour of Mars.

Red Planet: Scientific and Cultural Encounters with Mars must be used on a computer with a DVD-ROM drive because of its Web components. An educational tool suited best for libraries and schools, this title offers an interdisciplinary approach to Mars study. Touting more than four gigabytes of data, it's filled with hundreds of pages of text highlighting the scientific and cultural significance of Mars over the last two centuries. Science-fiction writers and planetary scientists ponder the social, philosophical, and economic values associated with our neighboring world in video segments whose topics range from early interpretations of telescopic observations to the modern debate of how and whether humans should go to Mars. Somewhat distracting and disappointing are the voice-over narration and the plain PowerPoint-type layout. More animations and videos from Mars missions would have made it even more educational and engaging.

Mars: The Red Planet earns high marks on its appealing "edutainment" style features and interactivity, while its DVD-ROM counterpart will more likely interest educators and students working on school projects. Both of these multimedia releases provide easy, user-friendly access to the volumes of data on Mars.
— **ANDREW S. FAZEKAS** *is a science writer and educator based in Montreal.*



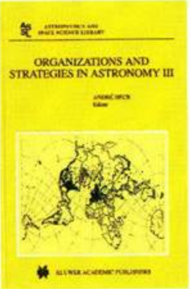
Minding the Heavens: The Story of Our Discovery of the Milky Way

Leila Belkora, 406 pages, Institute of Physics Publishing, Philadelphia, 2002; ISBN 0–7503–0730–7; softcover, $19.99. We earthlings have only recently come to know our place in the cosmos. Our early worldviews were childlike in their simplicity and self-absorption — our own planet was the center of a perfect universe. Now we know Earth orbits the Sun and that we live in the Milky Way, one galaxy among many. This book profiles seven visionaries — some famous, others obscure — who helped bring us to this self-awareness.

Observing Comets

Nick James and Gerald North, 234 pages, Springer-Verlag, New York, 2003; ISBN 1–8523–3557–2; softcover, $44.95. If you dream of joining the ranks of comet discoverers such as Halley and Hyakutake, this is the book for you. Part of Sir Patrick Moore's Practical Astronomy Series, *Observing Comets* provides clear descriptions of the anatomy and trajectories of these "dirty snowballs," as well as tips on viewing, photographing, and sketching them. Advanced amateurs will enjoy technical sections on image processing and spectroscopy, and an accompanying CD-ROM generates comet ephemerides.

Nick James and Gerald North
OBSERVING COMETS



Organizations and Strategies in Astronomy III

André Heck, editor, 234 pages, Kluwer, Boston, 2002; ISBN 1–4020–0812–0; hardcover, $115. Anyone interested in not only the scientific but also the sociological aspects of astronomy should find this volume enlightening. In thoughtful, clear essays, experts from various fields discuss the challenges of working on large research projects, the benefits of large telescopes, the evaluation process for National Science Foundation grants, the changing face of science journalism, the history of astronomy, as well as the state of research in nations from South Africa to Eastern Europe.

The Caldwell Objects

Stephen James O'Meara, 320 pages, Cambridge University Press, New York, 2003; ISBN 0–5218–2796–5; hardcover, $40. For those who have mastered the Messier list and are anxious to explore new territory, this volume on the 109 objects in the Caldwell Catalog should prove a helpful guide. The catalog was drawn up by eminent British astronomer Patrick Moore in 1995 to provide observers with intriguing targets spread evenly over the entire sky. O'Meara lists each object's location and other specs, then delves into its history and scientific importance. Photos and star charts supplement the text.

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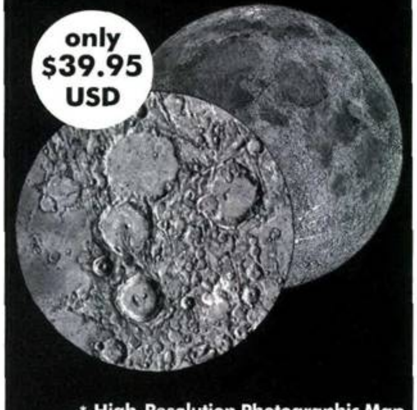

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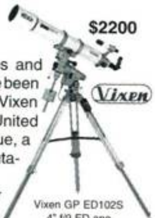
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AT1010 $499
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$4295

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Even though we sell an average of more than four 12" LX200 GPS scopes every week, it's only number four on our list of Meade go-to best sellers! Three other 8" and larger Meade go-to scopes outsell it. Will the new $4295 14" LX200 GPS now shipping from Meade also outsell the 12" LX200? We'll just have to wait and see. If it does, it will be because this impressively big telescope was the right telescope for those who bought one.

That's the reason we sell the most Meade telescopes – because we care enough to make sure that the scope you buy is the one that's right for you. Not the one we have too many of . . . not the one with the biggest profit . . . but the one that fits *your* needs, *your* abilities, *your* observing environment, and *your* budget. It's that kind of good service that keeps people coming back to buy from us again and again.

Want multicoated optics? They're standard on the NexStar 8 GPS.

NexStar 8 GPS
$2499

Celestron's **NexStar 8 GPS** Schmidt-Cassegrain has all the features you expect from a GPS scope (including Starbright high transmission multicoated optics for brighter images *at no extra cost)* plus some unique features unavailable in other GPS scopes!

For example, you can convert its unique Fastar 8" f/10 optical system to a blazingly fast f/1.9 focal ratio for wide field CCD imaging. With an optional Fastar lens assembly and a $1295 SBIG ST-237A CCD camera, the NexStar 8 GPS will record a huge 32 x 42 arc minute field. That's larger than the full Moon and more than three times the sky area imaged by a $7695 CCD camera on other 8" telescopes without Fastar optics!

Of all go-to telescopes, *only the Celestron NexStars have multicoated Fastar optics!*

The new Celestron CGE go-to telescopes are shipping *now.*

$4149
Celestron CGE1100

The wait is over. Celestron's CGE go-to German equatorial mount scopes are shipping on a regular basis. And our customers are telling us the wait has been worth it! CGE scopes solve the weight, vibration, and limited sky access problems of fork-mounted go-to Schmidt-Cassegrains. Even the 14" aperture CGE1400 can be set up by one person. The CGE German mount can see and photograph all parts of the sky, without the fork-mounted scope's need for an optional and expensive equatorial wedge or field derotator. And German mounts are famous for stability and lack of vibration.

Celestron multi-coated CGE scopes are available as complete go-to systems in apertures from 8" to 14". GPS is optional at only $199. You can get the CGE go-to mount alone for use with your own optics. Our website at **www.astronomics.com** has prices and full details.

A Celestron rechargeable battery for only $\$59^{95}$!

Why pay more for an ordinary 7 amp-hour 12V DC rechargeable battery, when Celestron's new **Power Tank** does so much more for less? It has *two* cigarette lighter plug outputs, not one. It has separate 3V, 6V, and 9V DC outputs to power accessories; a red lamp to set up your scope, an emergency spotlight; recharger, carrying strap, and more. ***At a mere $59⁹⁵**, it's an incredible value.*

Only $899 for a 5" *GPS-ready* Celestron SCT!

NexStar 5i
$899

The **Celestron NexStar 5i** is the *only* 5" telescope to have a fully automatic GPS go-to computer available as an option. No other 5" scope has GPS! Even better, the modular NexStar 5i lets you can build up to a GPS system gradually. Start at only $899 for the complete working tabletop scope shown right and add a computer, GPS, etc., whenever you want.

Starbright multicoated optics are *standard equipment* with the Celestron NexStar 5i. NASA uses Celestron 5" multicoated optics on the Space Shuttle. Don't your eyes deserve to see the same premium quality images?

Sell your used telescopes and accessories quickly for free by using the no-charge classified ads at

www.astrofieds.com

Why wait? We'll ship your Meade LX90 from stock.

Meade 8" LX90
$1695

The 8" **Meade LX90** lets you enjoy go-to astronomy for not a lot of money. The LX90 with standard optical coatings costs only $1695. Ultra High Transmission Coatings (UHTC) provide images up to 20% brighter for only $175 more. Both versions include a heavy-duty adjustable height tripod, 8 x 50mm finder, Autostar computer hand control with 30,223 star and object data base, and 26mm Super Plössl eyepiece.

We usually have LX90s in stock (both standard and UHTC versions), so you can probably get *your* LX90 with little or no delay. If Meade is shipping the LX90 *(or any Meade telescope)* for a dealer to keep in stock, the chances are good we *have* it in stock.

Meade prices are about the same anywhere you call. So why order a Meade product from a dealer who charges your credit card, then makes you wait and wait until he finally gets around to ordering what you want? Not when you can usually get the Meade telescope or accessory you want from stock . . . right now . . . at the right price . . . right here at ***astronomics.***

New Celestron ED eyepieces for only $\$64^{95}$!

Celestron's new *six-element* ED glass 55° field **X-Cel eyepieces** set new standards in affordable performance. Available in 2.3, 5, 8, 10, 12.5, 18, 21, and 25mm focal lengths. These parfocal eyepieces are fully *5-layer multi-coated*, with blackened lens edges for higher contrast. They have 20mm of eye relief and come in protective plastic cases. ***At only $64.95 each,** they are incredible visual values.*

Discovery Dobsonians are quality-made in the USA.

Why settle for a so-so imported Dobsonian when made-in-the-USA quality costs no more? Discovery mirrors are made in California by optical craftsmen and carefully hand figured for diffraction-limited images.

Each Discovery Dob has an adjustable metal mirror cell and 4-vane spider, *two* Plössl eyepieces, 2" metal rack and pinion focuser with 1.25" adapter, built-in tube balance system, tube carry handle, oversized bearings, 6 x 30mm finder, and tube end dust cover. For only $49 more, you can get two more Plössl eyepieces, eyepiece rack, second dust cover, and Moon filter!

Here are the prices for the 6" to 13.1" Discovery DHQ Dobs. Freight from the factory in California is additional, as shown.

6" f/5 Discovery DHQ	$\$339^{00}$	+ $49 freight
6" f/8 Discovery DHQ	339^{00}	+ $49 freight
8" f/6 Discovery DHQ	449^{00}	+ $49 freight
8" f/7 Discovery DHQ	449^{00}	+ $49 freight
10" f/4.5 Discovery DHQ	649^{00}	+ $69 freight
10" f/5.6 Discovery DHQ	649^{00}	+ $69 freight
13.1" f/4.5 Discovery DHQ	999^{00}	+ $185 freight

Premium DHQ Dobsonians with many upgraded features and accessories are available in 8" to 17.5" apertures starting at $799.

And for those who want easy set-up, trunk-of-the-car portability, and the light-gathering of a really *big* aperture, Discovery truss-tube Dobsonians are available in apertures from 12" to 24". Prices start at $1999.

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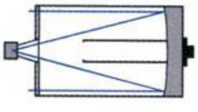
HyperStar™
High-Speed CCD Imaging

Now available for all Fastar-compatible Celestron SCTs

The HyperStar system allows CCD imaging at an amazing f/1.8 focal ratio (f/1.9 on 14" scopes). Images which might otherwise take hours now require just a matter of seconds! Plus, the wide field of view encompasses many large deep-sky objects normally not available to CCD imagers using SCTs.

6-minute HyperStar exposure of M20 with NexStar 11 GPS



The HyperStar lens allows a CCD camera to be mounted at the front of a Celestron Fastar-compatible SCT.

The HyperStar 8 and 11 models are ideal for high-speed CCD imaging with the NexStar GPS series of telescopes.

For the ultimate CCD imaging system, the HyperStar 14 is compatible with large-format CCD cameras, providing tack-sharp star images across an incredibly wide field!

★ *Available exclusively at Starizona* ★

Visit www.starizona.com/hyperstar for more details and images

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August 17-27, 2003

Join *Astronomy's* editors for a once-in-a-lifetime view of the Red Planet from a suite of sensational locations this autumn. Mars will be at its best in more than 2,000 years and will be highest in the sky – and therefore showing the most detail – from way down South.

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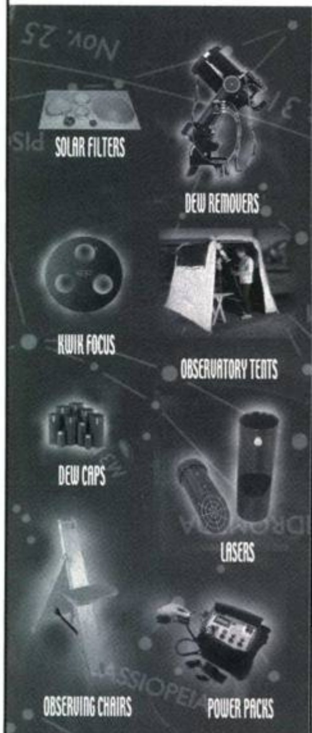

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NexStar 4GT - New lower price, improved features, and portability make this high performance GoTo telescope a must-have!

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Improved features include:

- **Two Star Alignment** — In addition to the NexStar's AutoAlign feature, users have the option of aligning on two known stars of their choosing.
- **Quick-Align** — Allows the telescope to align itself without being aimed at two alignment stars. A quick and easy way to get the NexStar 4GT tracking even in the Alt-Az position.
- **Filter Limits** — Displays only those objects within the set altitude filter limits.
- **Slew Limits** — Sets the limit that the telescope can slew in altitude.
- **RS-232 Compatible** — Allows the telescope to be controlled by a computer using popular astronomy software programs.

NexStar 5i and 8i - Expand your system as you expand your horizons.

The NexStar 5i and 8i include all of Celestron's newest hardware and software enhancements in an affordable and expandable system. Most important, these two new NexStar's will fully align themselves when used with the **optional CN16 GPS Accessory (#93963)**. Put the power of our newest software features and expanded object database to work with the **optional computerized hand control**.

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◀ NexStar® 4GT

NexStar® 4GT
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Optional Tripod:
$149

◀ NexStar® 8i

NexStar 8i shown with optional Computerized Hand Control, Tripod, 1.25" Ultima Ocular, and CN16 GPS Accessory.

Optional Computerized Hand Control (#93962) features include:

- **Database Filter Limits** — User-defined filter limits; only objects visible above the horizon are displayed on the hand control.
- **User-defined Slew Limits** — Prevents slewing beyond the user- defined horizon.
- **GPS Align Compatible** — When used with the optional CN16 GPS Accessory.
- **Hibernate** — Allows the NexStar to retain its star alignment even when powered down.
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New Software Features:

- **Compass Calibration** — Allows you to point to true north more accurately by compensating for magnetic north offset and local anomalies.
- **Polar Alignment Routine** — Facilitates polar alignment for CCD imaging or conventional 35mm astrophotography.
- **EQ AutoAlign** — Now the patented AutoAlign is available even when the telescope is mounted on a wedge.
- **Database Filter Limits** — Available in Equatorial mode as well as Alt/Az.

New Hardware Features:

- **AutoGuide Port** — Easy connection of AutoGuider for astrophotography.
- **Auxiliary Port** — Use for accessories like the optional CN16 GPS Accessory.

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NexStar® 5i ▶

NexStar 5i shown with optional Computerized Hand Control, Tripod, and optional accessories for astrophotography.

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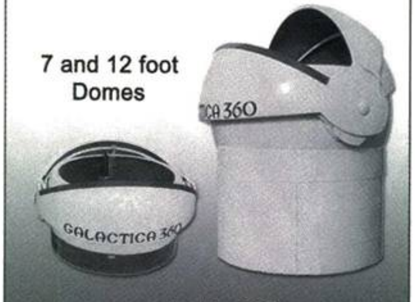

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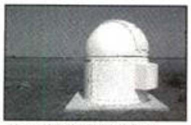

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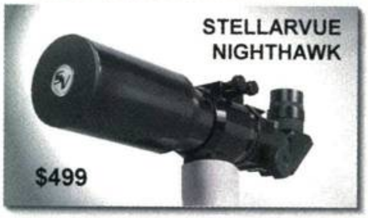

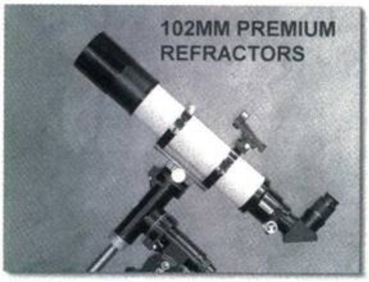

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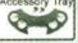

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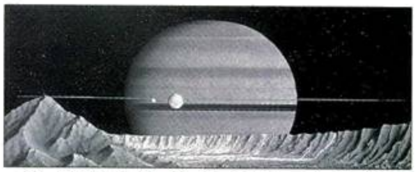

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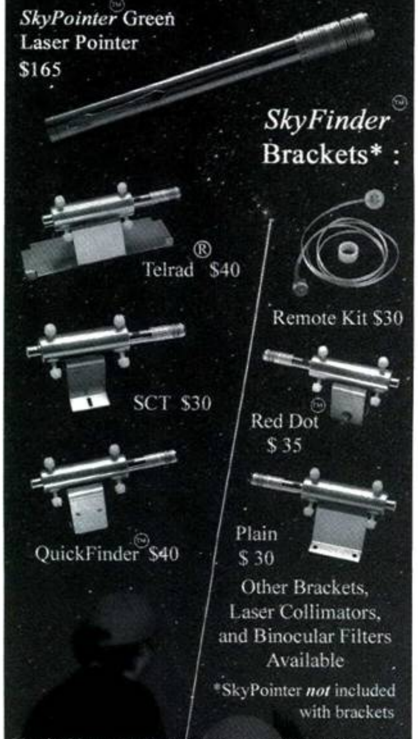

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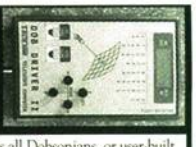

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07.09.03–07.12.03

Professional and amateur astronomers will gather at the Embassy Suites in Music City for ALCON 2003, the annual meeting for the Astronomical League. Sponsored by the Barnard-Seyfert Astronomical Society and the Astronomical League, the theme for this year's convention is "Amateur Astronomy's Next Decade."

THE MILKY WAY'S blankets of stars will delight observers during summer star parties. JERRY SCHAD

ALCON 2003 will feature speakers, vendors, awards, workshops, and presentations. Tours to Marshall Space Flight Center, U.S. Space and Rocket Center, and Dyer Observatory will also be part of the convention.

In addition to astronomical activities, conventioneers have much to choose from the surrounding area, including Andrew Jackson's Hermitage, the Grand Ole Opry, Civil War battlefields, and the Bicentennial Mall.

For more information, e-mail Mike Benson at ocentaurus@aol.com; website, http://bsasnashville.com/alcon2003.htm.

06.23.03–06.29.03

Laurel Highlands Star Cruise
Pine Hill Campground, near Hazleton, West Virginia. This event features dark-sky observing, workshops, prizes, and speakers. For more information, contact John Holtz at 724.352.7596; website, http://www.lhstarcruise.org.

06.27.03–06.28.03

Craters of the Moon Star Party
Craters of the Moon National Monument, near Arco, Idaho. This annual star party is co-sponsored by the Magic Valley Astronomical Society and Idaho Falls Astronomical Society. For more information, contact Mark Brandon at 208.357.3540; e-mail, skygaze@allidaho.com; or Jay Sneddon at 208.736.2447; e-mail, jaysneddon@yahoo.com.

07.10.03–07.15.03

Shingletown Star Party
Shingletown Airport, Shingletown, California. Previously held at Mount Lassen Volcanic National Park, this star party will move to a larger site at Shingletown due to increasing attendance. For more information, visit these

websites, http://www.observers.org, http://www201.pair.com/resource/resource-intl/ssp.html.

07.12.03–07.14.03

Gateway to the Universe

Munro Family Campground, Powassan, Ontario. Sponsored by the North Bay Astronomy Club, activities include stargazing, guest speakers, vendors, and a pre-owned treasures swap table. For more information, contact Tom Ouellette at 705.474.7666; Merlin Clayton at 705.472.1182; e-mail, galaxy@efni.com.

07.12.03–07.14.03

RocheStar Fest

Lewis S. Wolk Observatory, Ionia, New York. Sponsored by the Astronomy Section of the Rochester Academy of Science, this weekend of observing includes activities for the kids, a BBQ dinner, and guest speakers. For more information contact ASRAS at P. O. Box 20292, Rochester, NY 14602; e-mail, lenglund@frontiernet.net; website, http://rochesterastronomy.org.

07.24.03–07.26.03

Table Mountain Star Party

Table Mountain, near Ellensburg, Washington. This annual gathering is designed for amateur astronomers from beginners to seasoned veterans. For more information, visit the star party's website, http://www.tmspa.com/.

07.24.03–07.26.03

Weekend Under the Stars

Foxpark, Wyoming. Co-sponsored by the Cheyenne Astronomical Society, Laramie Astronomical Society, and Space Observers, events include junior astronomy classes, door prizes, observing, and speakers. For more information, contact Marty at 307.635.5944; email, curranm@attbi; website, http://www.home.attbi.com/-curranm.

07.25.03–07.28.03

Island Star Party

Victoria Fish and Game Association site, north of Victoria, British Columbia. For more information, contact Frank Ogonoski at 250.748.5110; e-mail, c.v.starfinders@shaw.ca; or Rich Willis at 250.881.7523; e-mail, richly@telus.net; website, http://starfinders.cvnet.net.

07.25.03–07.26.03

Arkansas Star Party

Devil's Den State Park, near Winslow, Arkansas. For more information, contact Joe Roam at 479.474.4740; e-mail, joeroam@aol.com; or Dale at daleh112@cox-internet.com.

07.25.03–08.03.03

Summer Star Party

Shady Pines Campground, Savoy, Massachusetts. Sponsored by the Rockland Astronomy Club, this family-oriented star party is a great way to spend summer vacation. For more information, visit the Rockland Astronomy Club's website, http://www.rocklandastronomy.com/specialevents.htm#SSP.

07.26.03

Cuyahoga Astronomical Association Annual Convention

CAA Observatory next to Letha House Park Barn, Chatham Township, Ohio. Hosted by the Cuyahoga Astronomical Association, a member of the Ohio Turnpike Astronomer's Association, this yearly gathering will feature a pot luck dinner and star party. For more information, contact Albert Matyas at 440.878.0258; email, amatyas@wideopenwest.com; or Art Nenadal at 440.779.7034; e-mail, VEGA77777@aol.com; website, http://www.geocities.com/cuyastro. ■

CONTACT INFORMATION

Please submit club announcements four months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Add your events to our online calendar at http://www.astronomy.com.

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RESOURCES

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GOLDILOCKS AND THE THREE PLANETS

BOOKS — A college-level look at climate models and meteorology can be found in John Houghton's *Planetary Atmospheres* (Cambridge University Press, Cambridge, Massachusetts, 2001).

WEB — The NASA Origins and Astrobiology programs seek to understand how life affects its surroundings, and to use this knowledge to detect life on other worlds through the program's environmental impact. This new and evolving field brings together biologists studying extremophiles on Earth with astronomers looking for atmospheres around distant planets. To find out more about this multi-disciplinary research, see: http://origins.jpl.nasa.gov and http://nai.arc.nasa.gov.

TRIAL BY FIRE

BOOKS — For a detailed yet concise account of both Soviet and American space missions, check out David Baker's useful *Spaceflight and Rocketry: A Chronology* (Facts On File, New York, 1996). Photographs, anecdotes, and data from both major space-faring nations fill Tim Furniss's *Manned Spaceflight Log* (Jane's Publishing, New York, 1986). Dennis Newkirk's *Almanac of Soviet Manned Space Flight* (Gulf Publishing, Houston, Texas, 1990) provides diagrams and accounts of each Soviet manned launch, and contextual essays on the quarter-century after Sputnik are collected in a symposium sponsored by the Smithsonian and the National Academy of Sciences in *The First 25 Years in Space*, edited by Allan Needell (Smithsonian Institution Press, Washington, D.C., 1983).

WEB — NASA maintains a number of excellent websites that serve as jumping off points for information searches on previous missions. Their history office is at http://history.nasa.gov; manned-mission lore can be found at http://spaceflight.nasa.gov; and astronaut interviews and photographs from the first Moon landing can be viewed at NASA's 30th-anniversary website for Apollo 11 at http://www.hq.nasa.gov/office/pao/History/ap11ann/introduction.htm. For information on the former Soviet Union's missions, visit space journalist Anatoly Zak's website at http://www.russianspaceweb.com.

SEEING SHARPER

ARTICLE — The latest scientific overview discussing the technology, equipment, and astronomical results of optical and infrared interferometry can be found in "Optical Interferometry" by Andreas Quirrenbach in *Annual Reviews of Astronomy and Astrophysics* (vol.39, pp. 353–401, 2001).

WEB — The promise of doing optical interferometry from space should be realized with the launch of the Space Interferometry Mission, scheduled for launch in 2006. To learn about NASA's plans for this landmark mission, as well as general background information on interferometry, visit http://planetquest.jpl.nasa.gov/SIM/sim_index.html.

SAGITTARIUS

BOOKS — If Sagittarius's 15 Messier objects aren't enough to satisfy your appetite for these celestial targets, pick up a copy of *Messier's Nebulae & Star Clusters*, second edition, by Kenneth Glyn Jones (Cambridge University Press, New York, 1991). This book dedicates several pages to each Messier object, providing finder charts, sketches, viewing instructions, historic quotes, scientific background, and other information.

WEB — For fans of planetary nebulae, the author recommends visiting Doug Snyder's Planetary Nebula Observer's Home Page at http://www.blackskies.com. The site provides, among other resources, background on these objects, tips for observing them, a large planetary nebula database, and images.

URANUS AND NEPTUNE

BOOKS — For more information about the seventh planet, read *Atlas of Uranus* by Gary E. Hunt and Patrick Moore (Cambridge University Press, Cambridge, Massachusetts, 1989). A great historical account of the prediction and discovery of the eighth planet is found in *The Neptune File: A Story of Astronomical Rivalry and the Pioneers of Planet Hunting* by Tom Standage (Berkley Publishing Group, New York, 2001).

WEB — Since the Voyager 2 mission that passed Uranus in 1986 and Neptune in 1989, NASA has maintained a number of great websites related to these planets. Two excellent sources for more information about Uranus and Neptune can be found at: http://pds.jpl.nasa.gov/planets/choices/uranus1.htm and http://nssdc.gsfc.nasa.gov/photo_gallery/photogallery-uranus.html. To access the Neptune pages at the above sites, simply substitute the word "neptune" for "uranus" in the web addresses.

STAR HILL INN

WEB – More information about Star Hill Inn, including contact information, may be found on its website at http://www.starhillinn.com/StarHillInn.html.

In addition to vacationing at a location such as Star Hill Inn, consider attending a major star party. There, you'll find lots of telescopes (many big ones!) whose owners will be happy to share views of heavenly objects with you. One of the largest of the summer star parties is the Table Mountain Star Party. Visit the website at http://www.tmspa.com.

Another great star party, usually held in the early fall, is the Okie-Tex Star Party. Find information about this event at http://www.okie-tex.com. If you're looking for a great event held outside of the warm summer months, the Winter Star Party may be for you. For more information, go to the WSP website, http://www.scas.org/wsp.html. ■

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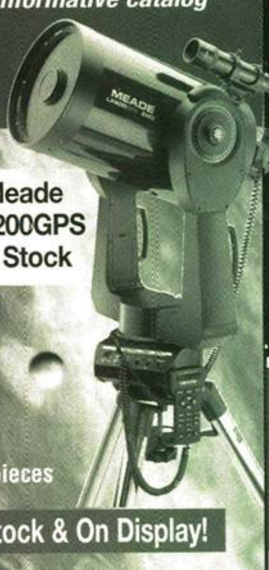

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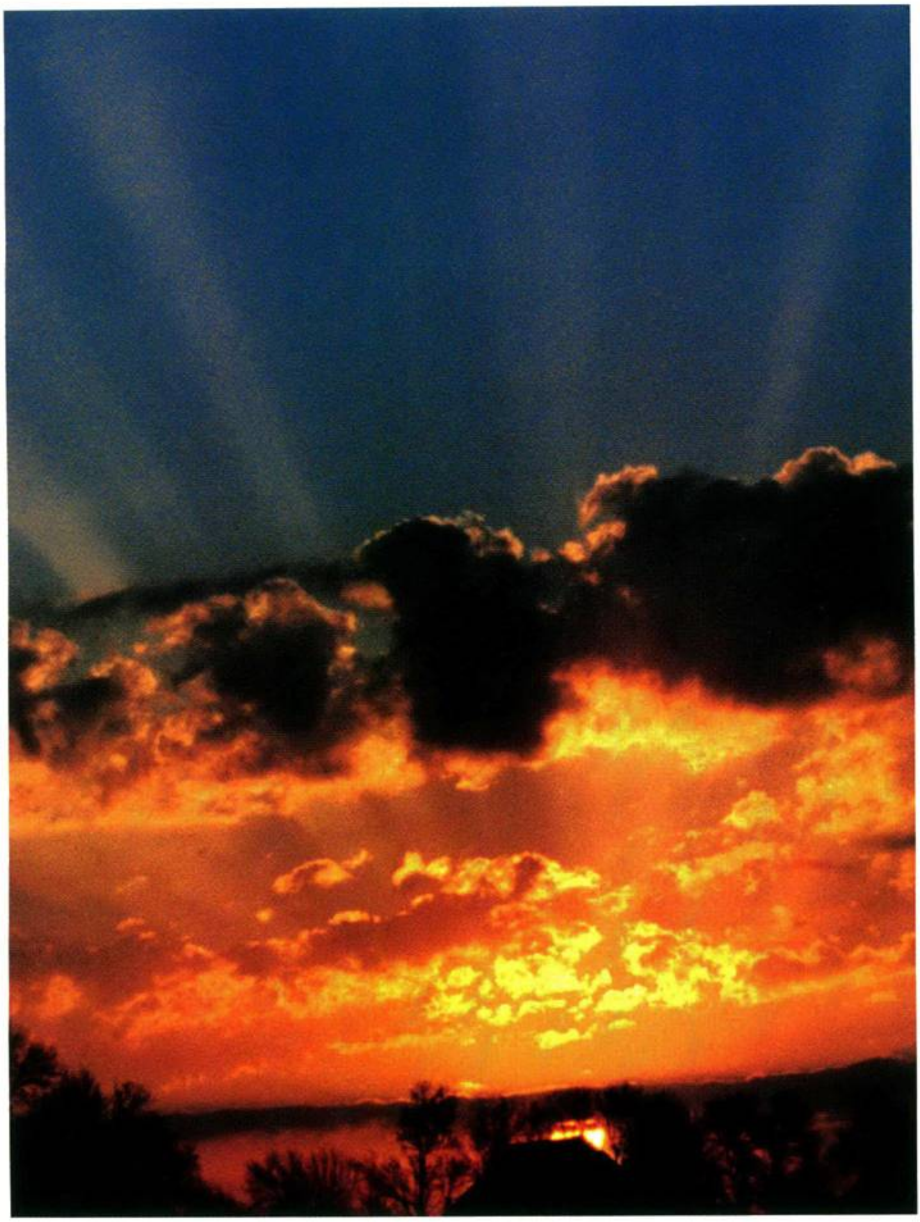
Crepuscular rays /// Jupiter /// The Helix Nebula /// Southern Arizona aurora
The Horsehead Nebula /// Mare Imbrium /// The Flaming Star Nebula



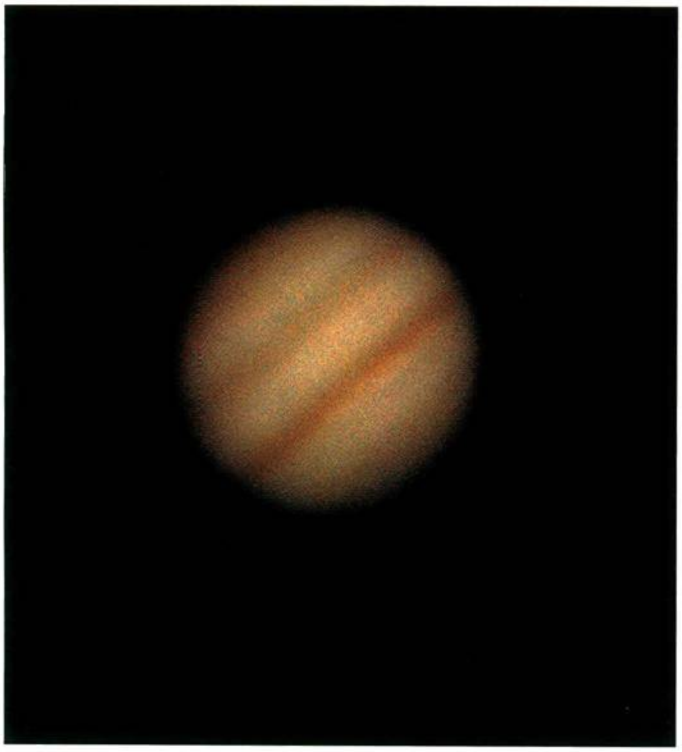
OBSERVING

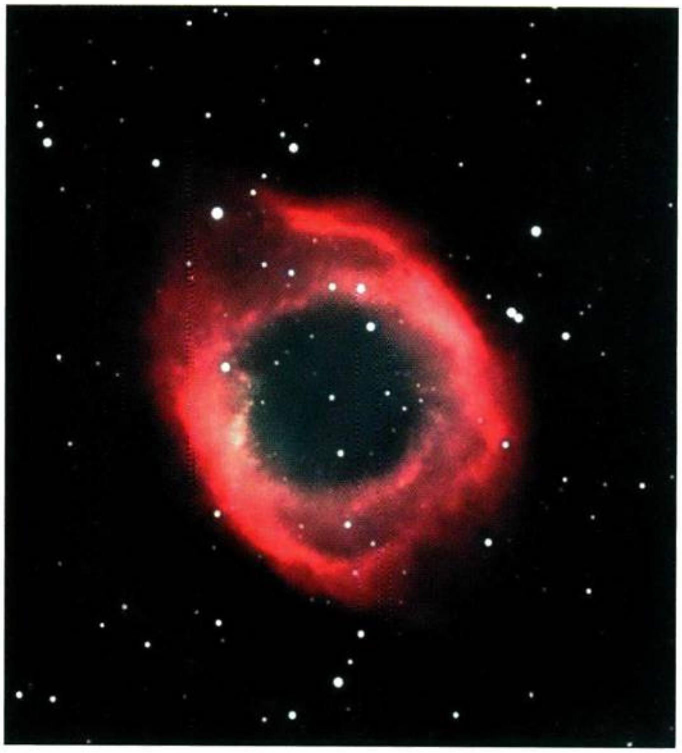
Crepuscular rays

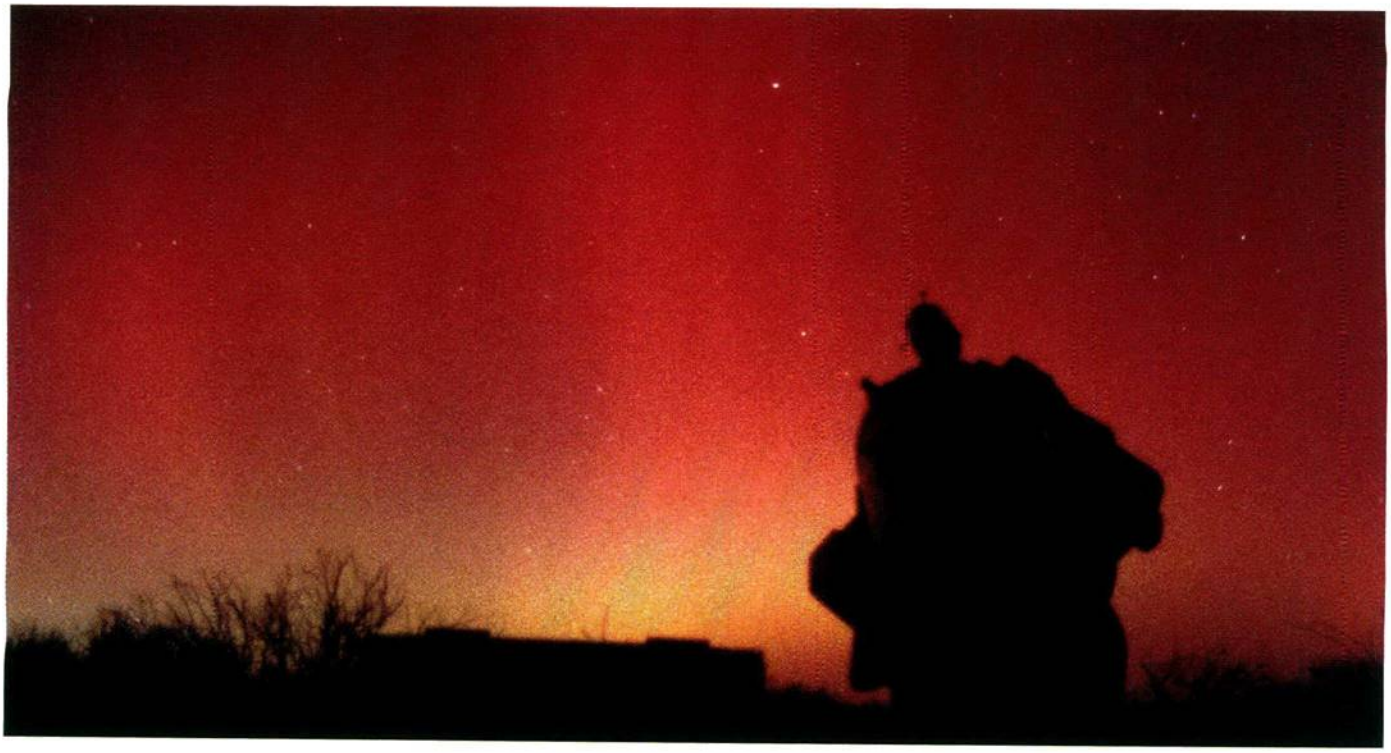
Carla Wehler caught this stunning sunset while photographing wildlife wetland areas in Kandiyohi County in Minnesota. A rural farm at harvest time created the perfect background for this gorgeous photo.

Crepuscular rays — beams of light radiating from the Sun — occur when a shadow is cast across the sky, usually by clouds. Most prominent just after sunset, these rays are visible due to sunlight being broken into darkened areas inside the shadow and lighted areas outside.

Left, **CREPUSCULAR RAYS AT SUNSET** (80mm lens at f/5.6, ISO 200 film, taken October 21, 2002, in Kandiyohi County, Minnesota) /// **CARLA WEHLER**







Top left. **JUPITER'S BELTS AND BANDS REVEALED** (Celestron 8-inch SCT at f/70, Fuji Superia 400 film, $^1/_2$-second exposure taken January 14, 2002) /// **GENE BARNES**

Top right. **THE HELIX NEBULA** (NGC 7293) (Astrophysics 5-inch apochromatic refractor at f/6, SBIG ST-8E CCD camera, composite exposure) /// **RICHARD JACOBS**

Above. **FAR SOUTHERN AURORA AND TELESCOPE** (17mm lens (fixed) at f/3.5, Ektachrome 1600 film, 80-second exposure taken March 30, 2001) /// **DAVID HEALY**

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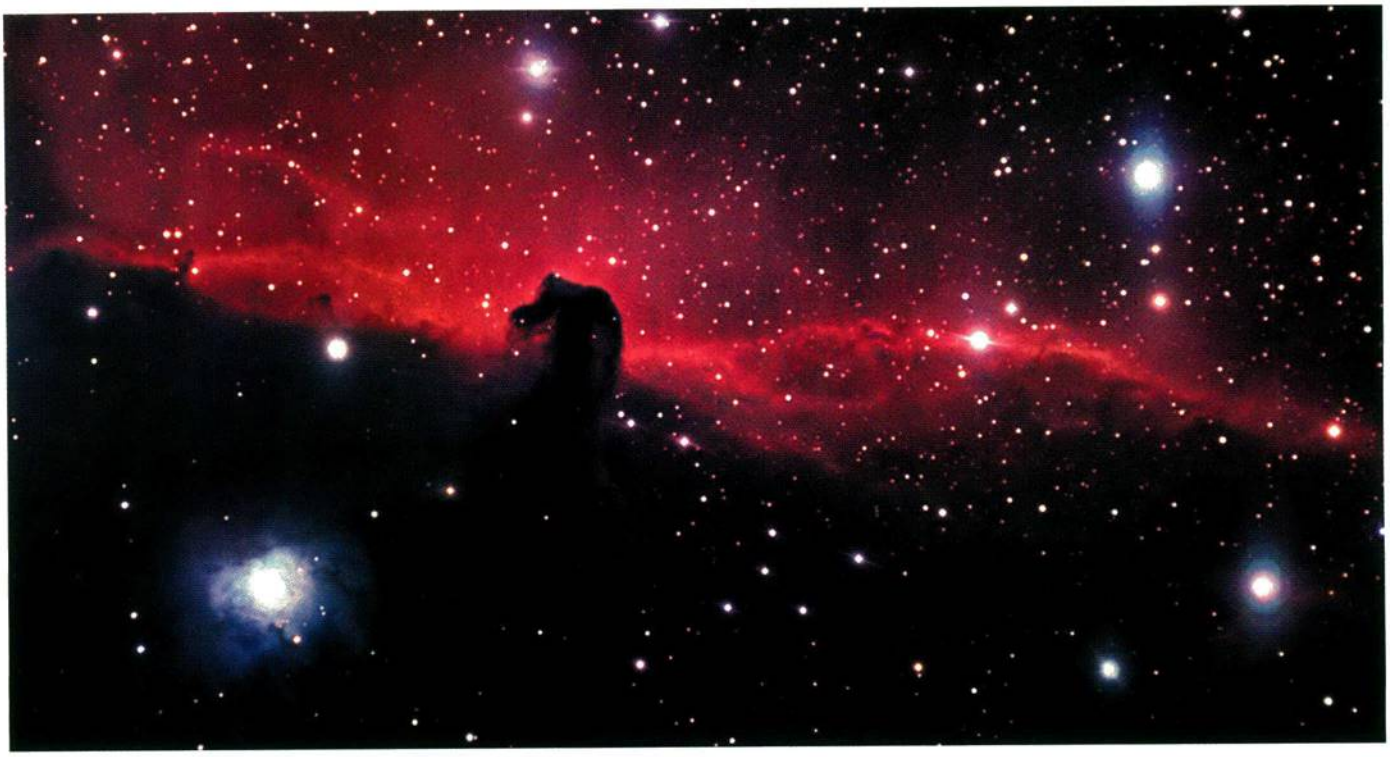
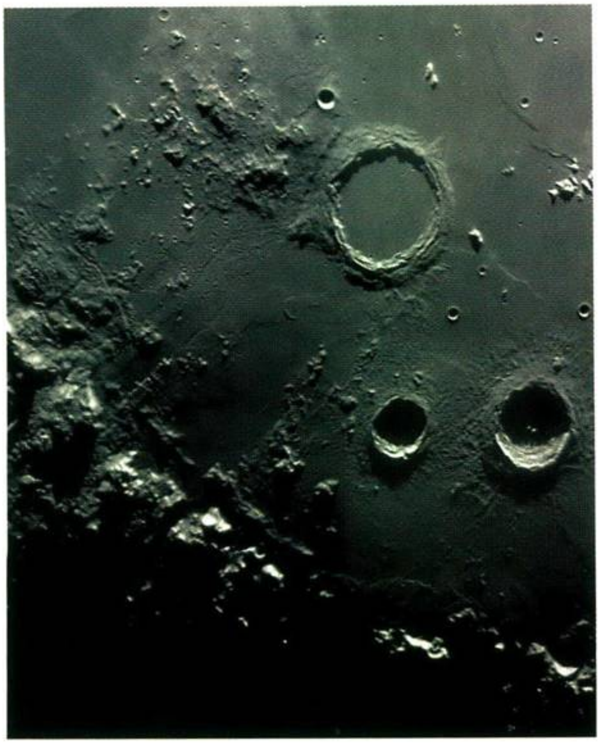
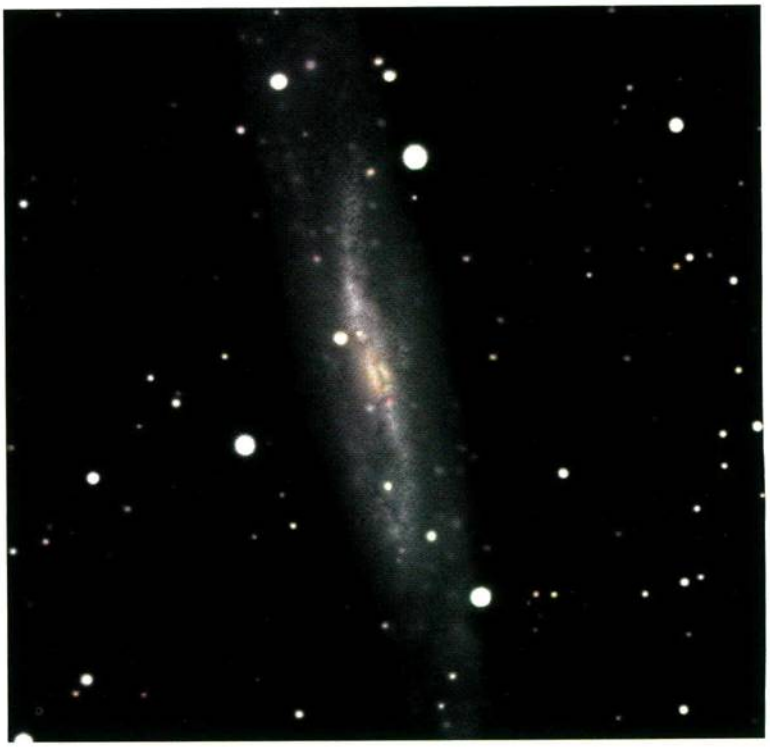
Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.





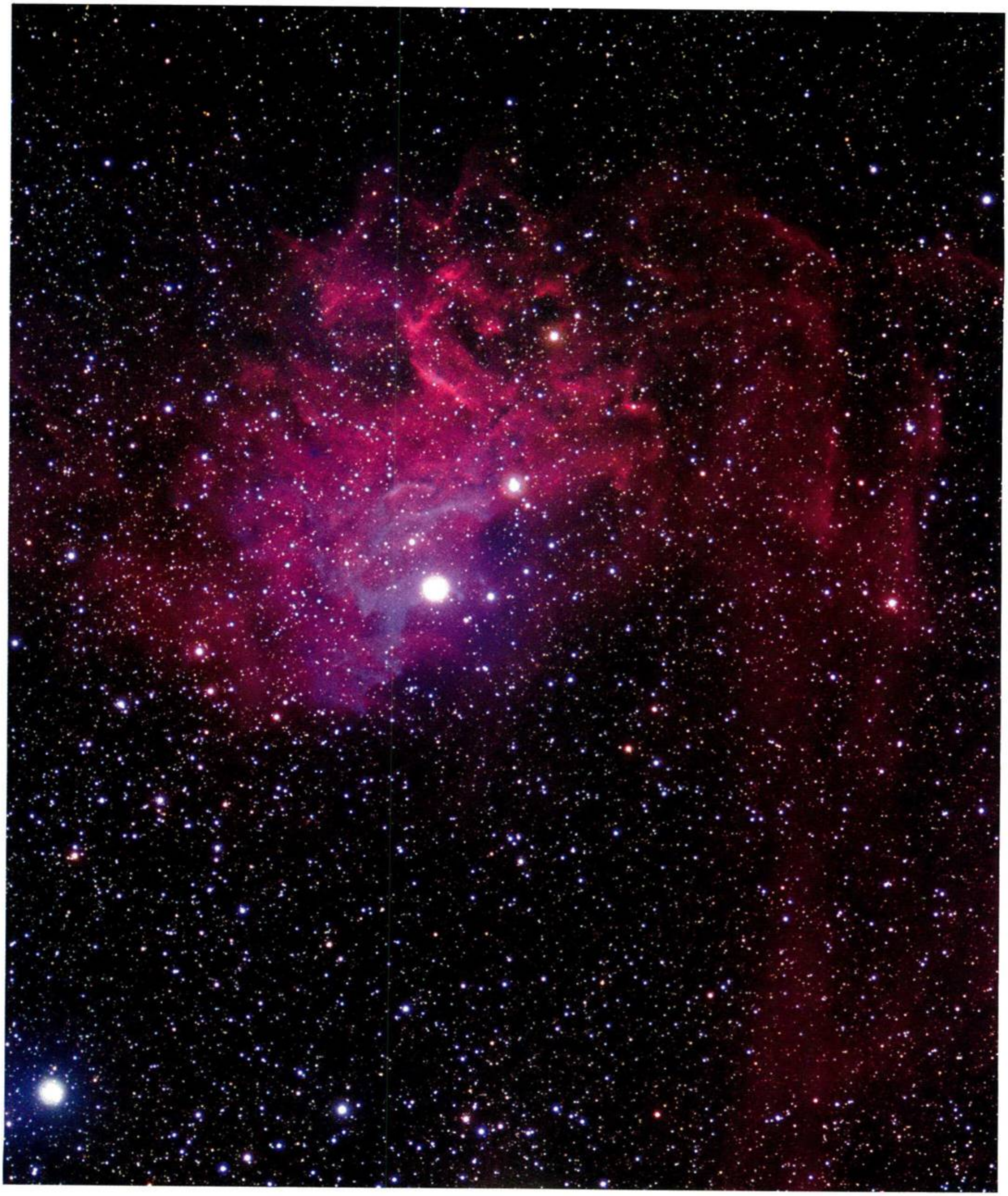


Top. **THE HORSEHEAD NEBULA** (B33) and IC 434 (Astrophysics 5-inch apochromatic refractor at f/6, SBIG ST-8XE CCD camera, composite exposure) /// **RICHARD JACOBS**

Bottom left. **THE MARE IMBRIUM REGION** (Celestron 11-inch SCT, Astrovid 2000 video camera, composite of 12 images taken September 20, 2000) /// **CRAIG ZERBE**

Above. **SPIRAL GALAXY NGC 7640** in Andromeda (Meade 12-inch SCT at f/6.3 (focal reducer), SBIG ST-7E CCD camera, composite exposure) /// **RALPH SARGENT**

Below, **THE FLAMING STAR NEBULA** in Auriga (IC 405) (Astrophysics 5-inch refractor at f/8, Kodak Tech Pan film, composite exposure) /// **CHUCK VAUGHN**



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